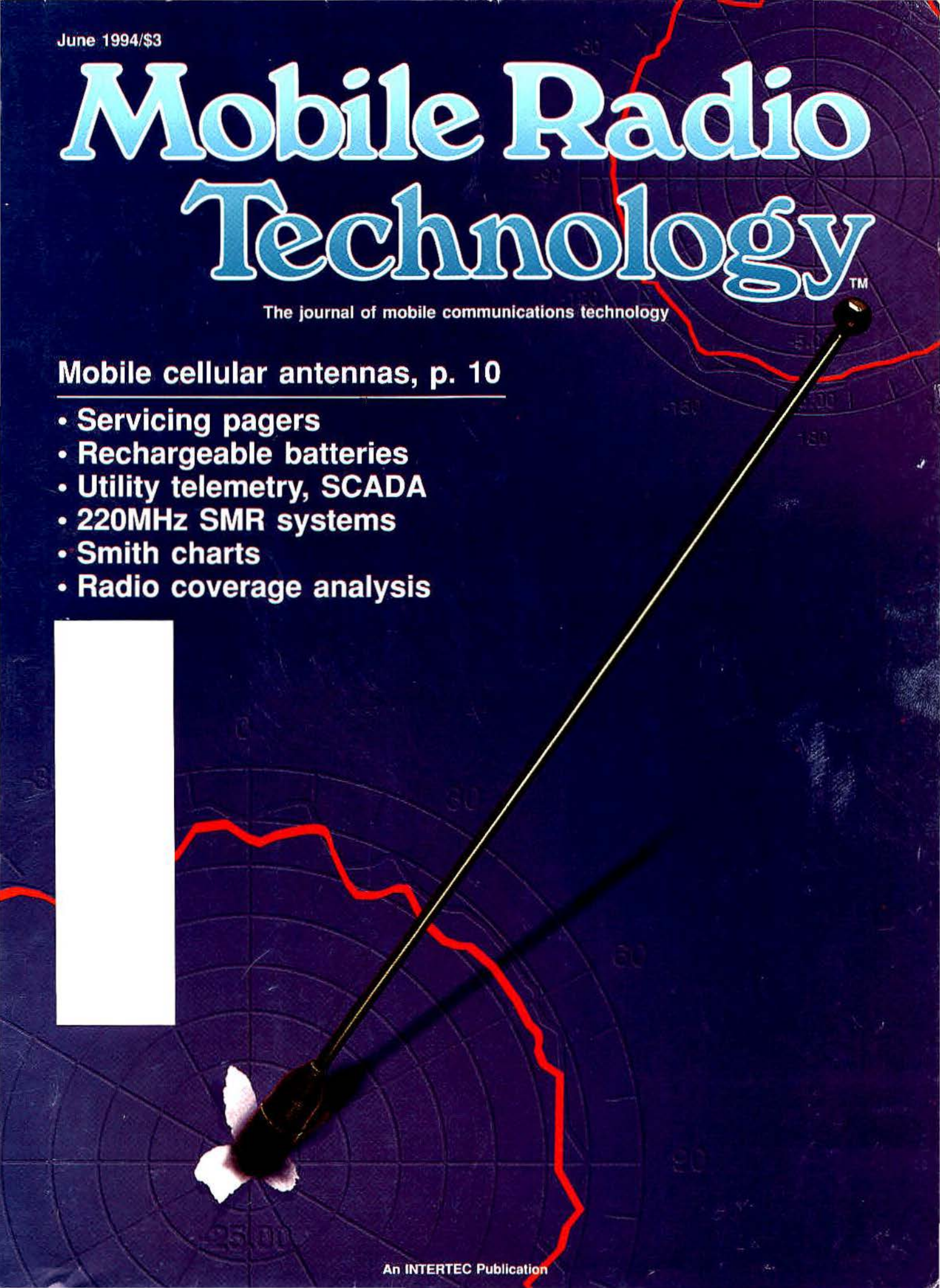
June 1994/$3

Mobile Radio Technology™

The journal of mobile communications technology



Mobile cellular antennas, p. 10

- Servicing pagers
- Rechargeable batteries
- Utility telemetry, SCADA
- 220MHz SMR systems
- Smith charts
- Radio coverage analysis

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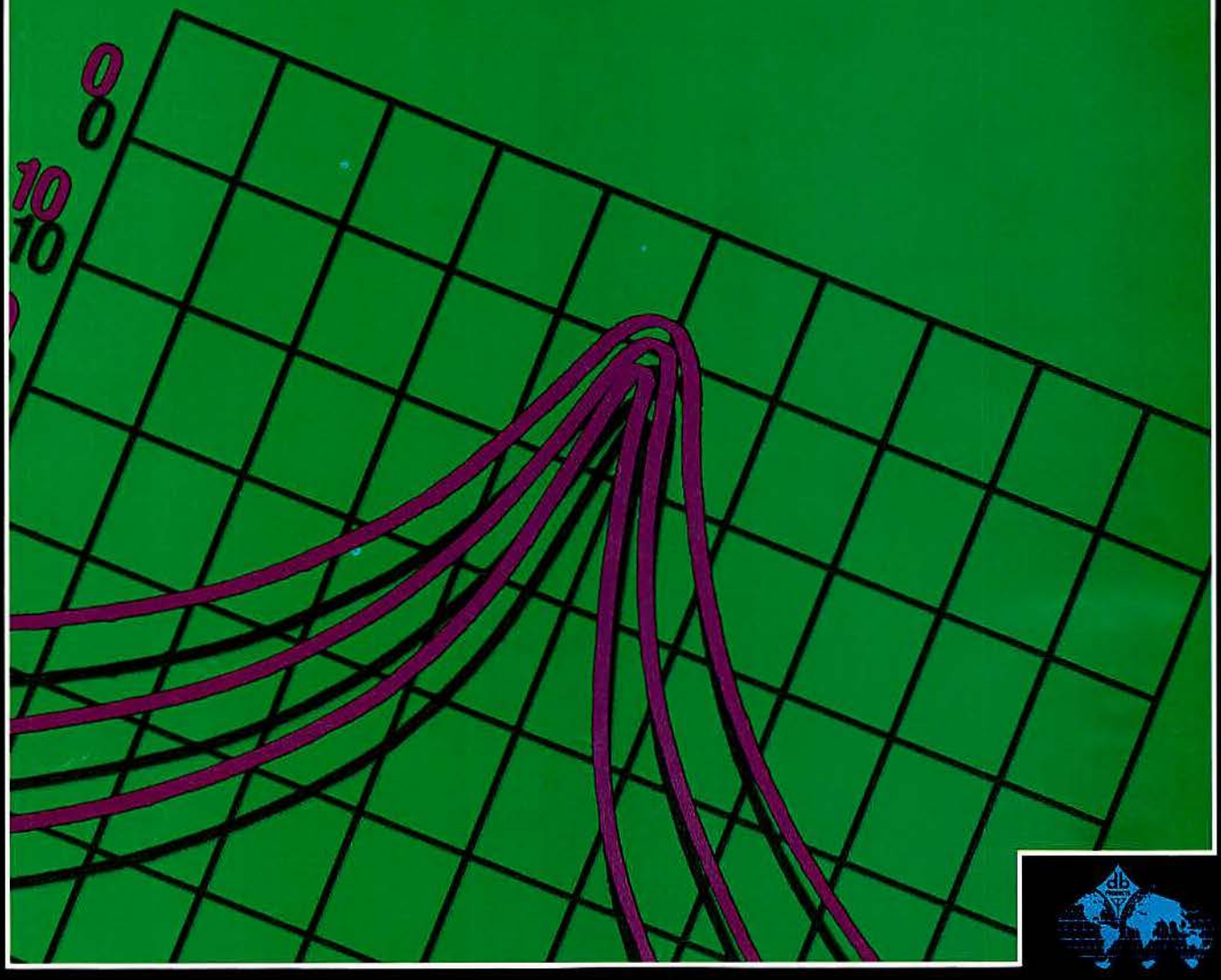

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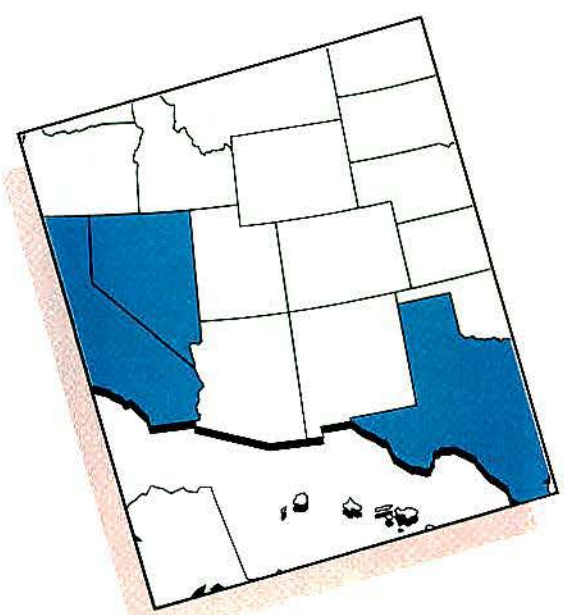

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features

On the cover: Various mobile antennas fit urban, suburban and mixed environments. See Kim Goryance's article on page 10. *Artwork courtesy of Allen Telecom Group, Cleveland.*

departments

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Regional Communications systems manager is 'Technician of the Year'

Congratulations to John Murphy, the recipient of the 1994 Technician-of-the-Year Award.

John Murphy

Murphy is employed as a systems manager with Regional Communications, Paramas, NJ. He has worked for Regional since 1982. He is responsible for the development, installation and maintenance of paramedic dispatch systems, hospital paging systems, mobile data systems and specialized mobile radio (SMR) systems.

Murphy has a technician's certificate from the National Association of Business and Educational Radio (NABER), an FCC General Radiotelephone Operator license and a New Jersey state electrician's license.

"I can tell you from the sales side of the house," explained Jim Faherty, Regional's territory sales manager, "John's technical talents and his ability to wrap his arms around the customer make him one of my most powerful sales weapons."

Faherty explained that there are a lot of issues to discover in selling large communications systems. Not all of them can be discovered at the outset, so a certain number of problems have to be resolved while the project is under way. "If there is a problem, John has a way of getting alongside the customer and explaining what is going on," he said. "He has a way of smoothing things over until the problem is solved." The sales and technical departments work as a team in selling large systems, and "John is the guy I want to go in the door with," Faherty said.

Wayne Root, Regional's field service manager, nominated Murphy for the award. "His name has become a household word among our customers," Root said. "Whenever they need him for something, he's there, whatever the time. We almost have to force him to take a vacation."

Root said that Regional's work as a systems integrator requires familiarity with many products in addition to land mobile radio. "There isn't anything we work on that John hasn't grabbed hold of and learned to do. He can juggle multiple projects and accomplish an enormous amount in a short time."

In his role as systems manager, Murphy sometimes conducts training classes for Regional's technicians. "When we put new technologies or systems in place, John is exposed to the most sophisticated equipment and software," said Regional's President, Tony Sabino. "John compiles the information and then conducts a training class for the technical staff."

The Tech-of-the-Year award recognizes the vital role technicians play in the industry. It honors technicians who are actively employed in mobile communications and who have shown an outstanding effort in the performance of their duties. Candidates are assessed on their professionalism, performance, customer satisfaction and teamwork abilities.

Murphy was scheduled to be honored at a May 13 luncheon in Orlando, FL, during the Mobile Comm '94 conference.

The award and conference are sponsored by NABER, an organization that deserves a lot of credit for raising the visibility of radio technicians through its award program. If you are interested in submitting a nomination for next year's award, call Jan Jensen at 800-759-0300.

* * *

SMR action

There is plenty of action to watch this month when it comes to the specialized mobile radio (SMR) segment of the land mobile radio industry.

▶ *Analog vs. digital*—Market research companies are publishing reports that subscriber numbers among analog SMR businesses are going to decline because of competition from feature-rich digital SMR businesses. Analog SMR system operators in Los Angeles, meanwhile, say they are largely successful in retaining their own customers while *gaining* customers from competitors that switch to digital and raise prices. Which is it really going to be, decline or gain for analog SMR?

▶ *Application mills*—A potential digital SMR system operator has contracted to buy 600 channels from a court-appointed receiver who controls SMR licenses flowing from the Federal Trade Commission's efforts to protect the public from application mills. "Spectrum Junk Bond Traders," page 74, which was written before the purchase announcement, gives the background. Who should get the channels, bulk purchasers or a new round of applicants?

▶ *David vs. Goliath*—An analog SMR operator has asked the FCC to revoke licenses held by the largest digital SMR operator. The legal argument involves foreign ownership. (See "SMR Operator Urges FCC To Revoke Nextel Licenses," page 77.) Will the matter be decided on legal merits or political considerations, or will there be a monetary settlement between the two adversaries?

—Don Bishop

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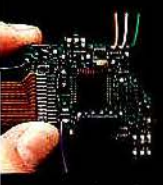

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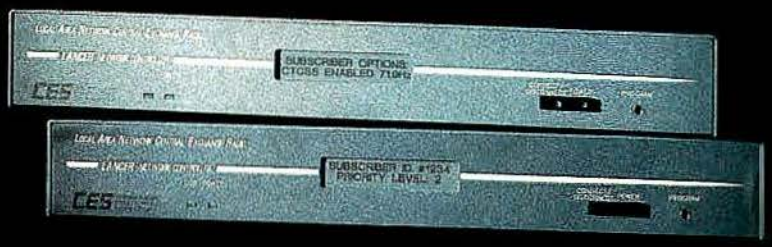

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Calendar

June

7-11—Vehicular Technology Conference, sponsored by IEEE Vehicular Technology Society, Stockholm, Sweden. Contact: Professor Sven-Olof Ohrvik, technical chairman, 46 8 757 0483; Fax 46 8 34 8441.

18-20—International Public Safety Exposition and Conference, sponsored by the International Association for Public Safety, Dallas Convention Center, Dallas. Contact: 203-847-9679.

19-23—Utilities Telecommunications Council, Washington Sheraton, Washington, DC. Contact: Christine Benz, 202-872-0030.

28-30—Wireless Datacomm Spring, San Jose Convention Center, San Jose, CA. Contact: 800-322-9332.

July

17-20—Forestry-Conservation Communications Association, Hershey, PA. Contact: Don Pfohl, 602-644-3166.

August

6-11—International Municipal Signal Association, Cavenaugh's Inn, Spokane, WA. Contact: Harold Glerum, 800-723-4672.

7-12—Association of Public-Safety Communications Officials—International National Conference, Lawrence Convention Center, Pittsburgh. Contact: 800-824-1850.

September

22-24—Personal Communications Showcase, Washington State Convention Center, Seattle. Contact: 800-326-8638.

27-Oct. 1—International Conference on Universal Personal Communications, sponsored by the Institute of Electrical and Electronics Engineers, Hyatt Regency San Diego, San Diego. Contact: Nokia Mobile Phones, 800-306-6542.

October

3-5—WirelessWorld Conference & Exhibition, sponsored by *Cellular Business* magazine, The Stouffer Orlando Resort, Orlando, FL. Contact: Chris Lotesto, 800-458-0479.

19-21—International Wireless Communications Expo/Fall, Tampa Convention Center, Tampa, FL. Contact: 800-828-0420.

November

3-5—Industrial Telecommunications Association and **Council of Independent Communication Suppliers Annual Meetings,** The Kingsmill Resort and Conference Center, Williamsburg, VA. Contact: Barbara J. Levermann, 703-528-5115.

9-13—CMA '94, sponsored by the Communications Marketing Association, Radison Plaza Lord Baltimore Hotel, Baltimore, MD. Contact: Jack Armstrong, 410-628-9300.

18—Radio Club of America, Communications Symposium, 85th Anniversary Dinner and Awards Presentation, New York Athletic Club, New York: Contact: Ron Formella, 201-652-6811.

December

6-8—Wireless Datacomm Fall, Washington Convention Center, Washington, DC. Contact: 800-322-9332.

1995

February

1-3—Cellular Telecommunications Industry Association Winter Meeting and Exposition, New Orleans. Contact: 202-785-0081.

March

20-23—Supercomm, sponsored by USTA and TIA, Anaheim Convention Center, Anaheim, CA. Contact: 202-326-7300.

April

3-5—Energy Telecommunications and Electrical Association, George R. Brown Convention Center, Houston. Contact: 214-235-0655.

25-27—International Wireless Communications Expo/Spring, Las Vegas Sands Convention Center, Las Vegas. Contact: 800-828-0420.

May

30-June 2—Radiocomm, Toronto Metropolitan Convention Center, Toronto. Contact: 613-233-4888.

July

26-28—Vehicular Technology Conference, sponsored by IEEE Vehicular Technology Society, Hyatt Regency Chicago O'Hare, Chicago. Contact: Keith Paglusch, chairman, 312-399-2378.

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The journal of mobile communications technology

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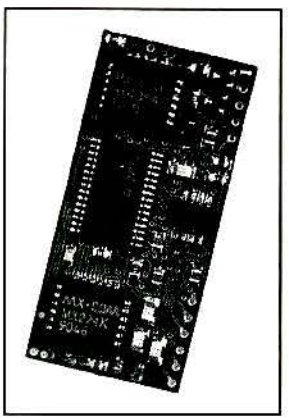

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Impedance, admittance and the Smith chart, part 2

By Harold Kinley, CET

Last month, impedance and admittance were covered as a prelude to using the Smith chart. This month let's take a brief look at the Smith chart.

Phillip H. Smith developed the Smith chart more than 50 years ago. (See "Charting the Unseen, page 70.)

Smith charts are available through Analog Instruments, P.O. Box 808, New Providence, NJ 07974. Phone or fax (908) 464-4214. Other instruments developed by Smith are also available through Analog Instruments, as well as his book: *Electronic Applications of the Smith Chart*. This book is recommended reading for anyone working with antennas and transmission lines.

Figure 1 to the right is a skeletal representation of the full-blown *standard* Smith chart. Coordinates on the standard Smith chart, [FORM 82-BSPR(9-66)] can represent either *admittance* (Y) or *impedance* (Z) in *normalized* form. The horizontal axis of the big circle represents *pure resistance* or *pure conductance*. The arcs lying below the horizontal axis represent either capacitive reactance or inductive susceptance. These arcs are part of a circle whose origin lies at a point off the chart. The arcs lying above the horizontal axis represent either inductive reactance or capacitive susceptance. The full circles having a common point of tangency at the far right of the horizontal axis represent resistance. The circle tangent to the center of the big circle has special importance. It is called the *unity resistance* or *unity conductance* circle. The large circle which intersects the horizontal axis at the zero resistance point on the left is called the *pure reactance* or *pure susceptance* circle.

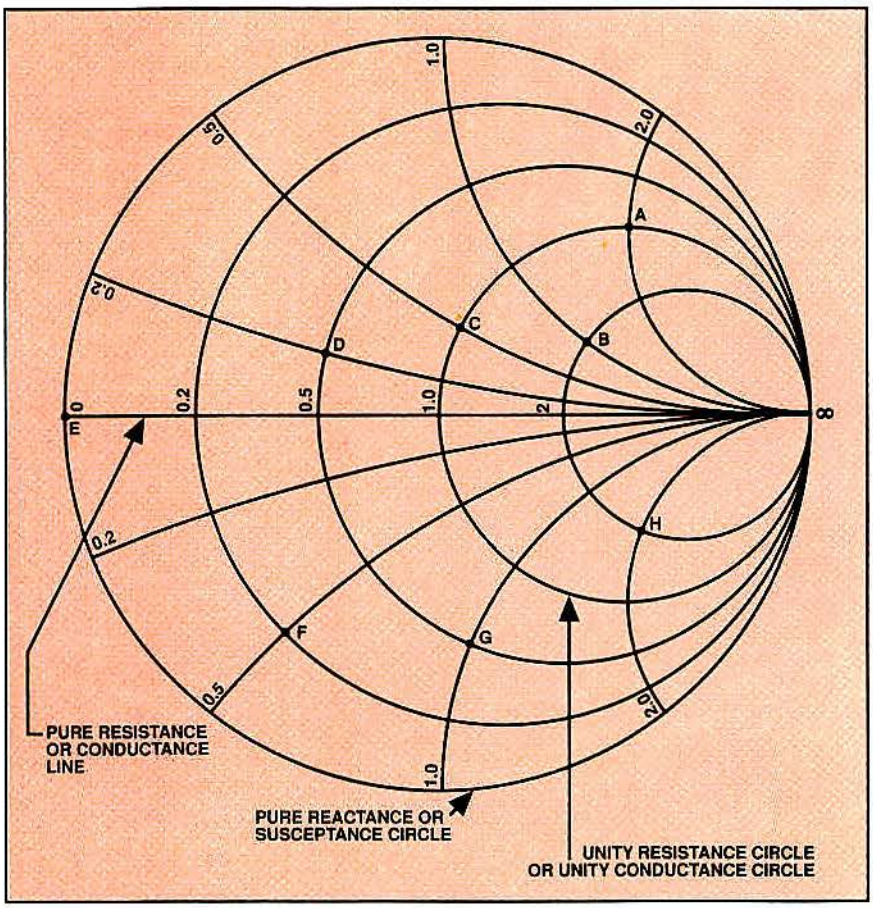

Figure 1: This is a skeletal view of the Smith chart.

Normalization

Complex *impedances* in the form ($R \pm jX$) are normalized by *dividing* the expression by the *system impedance*, Z_0. For example, the complex impedance ($50 + j100$) in a 50Ω system impedance is normalized to $(50 + j100)/50 = (1.0 + j2.0)$. This is represented by Point A on the chart in Figure 1.

Complex *admittances* of the form ($G \pm jB$) are normalized by *multiplying* by the *system impedance*, Z_0 (or *dividing* by the *system admittance*, Y_0). The complex admittance ($0.02 + j0.04$) is normalized to $50(0.02 + j0.04) = (1.0 + j2.0)$. Again, this is represented by Point A on the chart in Figure 1. Table 1 on page 66 lists all of the points on the chart in Figure 1 along with the equivalent values of complex impedance, complex admittance, and the normalized values of both Z_N and Y_N.

Note on Table 1 that the system admittance is labeled as 20mS SYSTEM Y. This is 20 milli-siemens. Remember from last month that admittance is the reciprocal of impedance (1/Z) and is measured in siemens (S). The old term was mhos. $1/Z = 1/50 = 0.02S$ (siemens) or 20 milli-siemens or 20mS. Smith charts representing admittance in 50Ω systems are called 20 *Millimho characterstic admittance* charts. Charts are also available which represent 50Ω *characteristic impedance*.

When these special impedance or admittance charts are used, the complex value of impedance or admittance does not have to be normalized. Even so, there are offsetting disadvantages to using these charts. The 50Ω impedance chart can only represent impedance in 50Ω systems. (Admittance values can not be represented on this chart.) Similarly, the 20mS admittance chart can only be used to represent admittance values in a 20mS system admittance (50Ω system impedance). (Impedance values can not be represented on this chart.)

On the other hand, the normalized impedance or admittance chart can be used to represent *either* admittance (Y) or impedance (Z) in *any* system impedance (Z_0) or admittance (Y_0). We will stick with the standard normalized chart here.

Constant VSWR circle

Suppose that a transmitter (generator) is connected to a load through a transmission line. The system impedance, Z_0, is 50Ω. However, the load impedance is a mismatched complex impedance of ($150 \pm j0$)Ω. This is normalized to ($3 \pm j0$) and is

(continued on page 60)

Kinley is a certified electronics technician with the South Carolina Forestry Commission, Spartanburg, SC. He is the author of *Standard Radio Communications Manual: With Instrumentation and Testing Techniques*, Prentice-Hall, 1985.

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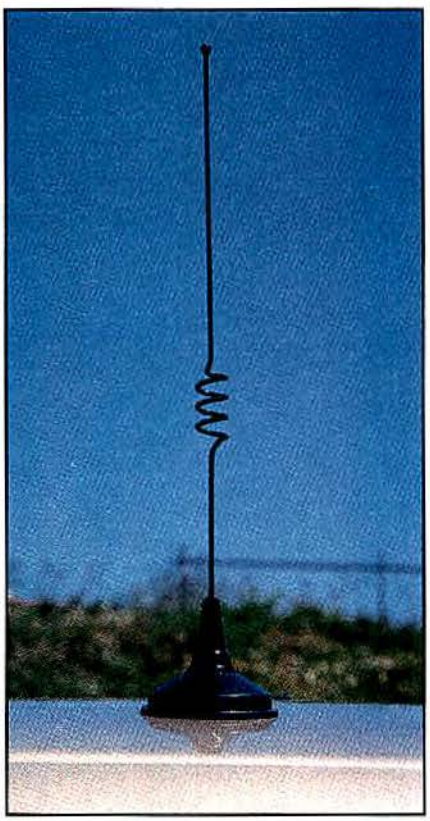
How to choose the 'best' mobile antenna

Selecting the best antenna for the type of use is the key to a clear, high-quality connection. Important factors include mounting types, decibel gain and the use of solid-state technology for mechanical strength.

By F. Kim Goryance

Every day, about 11,000 people become new cellular telephone subscribers. The reasons for deciding to subscribe differ from person to person. For some, it is a matter of yielding to peer pressure from friends and business associates. Others have succumbed to ever-present radio commercials for cellular service that they hear while stuck in traffic, deciding that they would rather talk with someone than to listen to old songs and prattling disc jockeys. Some probably get tired of stopping to use a pay phone when they are paged or when they realize they are going to be delayed. Perhaps they simply want to make better use of their time and to work more efficiently. Whatever the reason, the decision to have a mobile cellular phone installed has been made—and a few more decisions must follow.



The roof-mount antenna ensures good performance and requires garage-door clearance.

When choosing a new or upgraded mobile phone system, people usually spend most of their time deciding which phone to buy. After all, the handset is the most important element in the system, right? Not necessarily. Obviously, selecting the phone is part of equipping a vehicle with cellular communications, but it is not the whole story. Selecting the best antenna for the type of use the subscriber is expected to make of the phone is the key to a clear, high-quality cellular connection.

Place your bets

Most first-time subscribers, and a high percentage of experienced users, generally fail to recognize the antenna's importance to the phone's performance. It may be the least glamorous part of owning a mobile phone, but when it comes to call clarity, the antenna is the most crucial component. The antenna is the first point of reception and the last line of transmission. A subscriber's perception of a carrier's service can be tainted if an improper or inferior antenna is hindering the phone's performance.

Consider the new user who has a free mobile phone installed as a subscription incentive. The carrier sponsoring the incentive wants that new subscriber to be completely satisfied with the service and to renew the contract when it expires. This kind of incentive plan has become relatively common in highly competitive metropolitan markets. Carriers "bet" a free mobile phone that the new subscriber will realize the benefits of mobile communications and be pleased enough with the service to continue subscribing for a long time. An inferior antenna has the potential to stack the deck against the carrier.

Areas in which the mobile phone will be used are as varied as the individuals who use them. Some people spend virtually all of their time in metropolitan areas, whereas others travel extensively between cities. Commuters who live in a suburb and work in a nearby city use their phones differently from those who live and work on a farm or ranch. Cell sites have varying signal levels in these dissimilar surroundings.

Equipping a subscriber with a reliable phone can hinge on using an appropriate antenna that is designed for the user's particular application and environment. It is relatively common for both the subscriber and the installer to overlook the importance of the antenna. Because different types of antennas are better suited for certain areas, care must be taken to match the user's needs with the proper antenna gain.

Another consideration is the antenna mounting location. The type of vehicle will play a role in deciding between a glass-mount, roof-mount or trunk-mount antenna. Whether the user is willing to have a hole drilled in the vehicle also can be the determining factor.

Decisions, decisions . . .

Subscribers need to be made aware of the different types of antennas and the applications for which each is best suited. Do not let a new subscriber make a snap decision and select the first antenna he sees. To ensure the clearest possible connection, and possibly a subscriber's loyalty to a carrier, the right antenna for the user's environment must be installed.

Goryance is director of marketing, Allen Telecom Group, Cleveland

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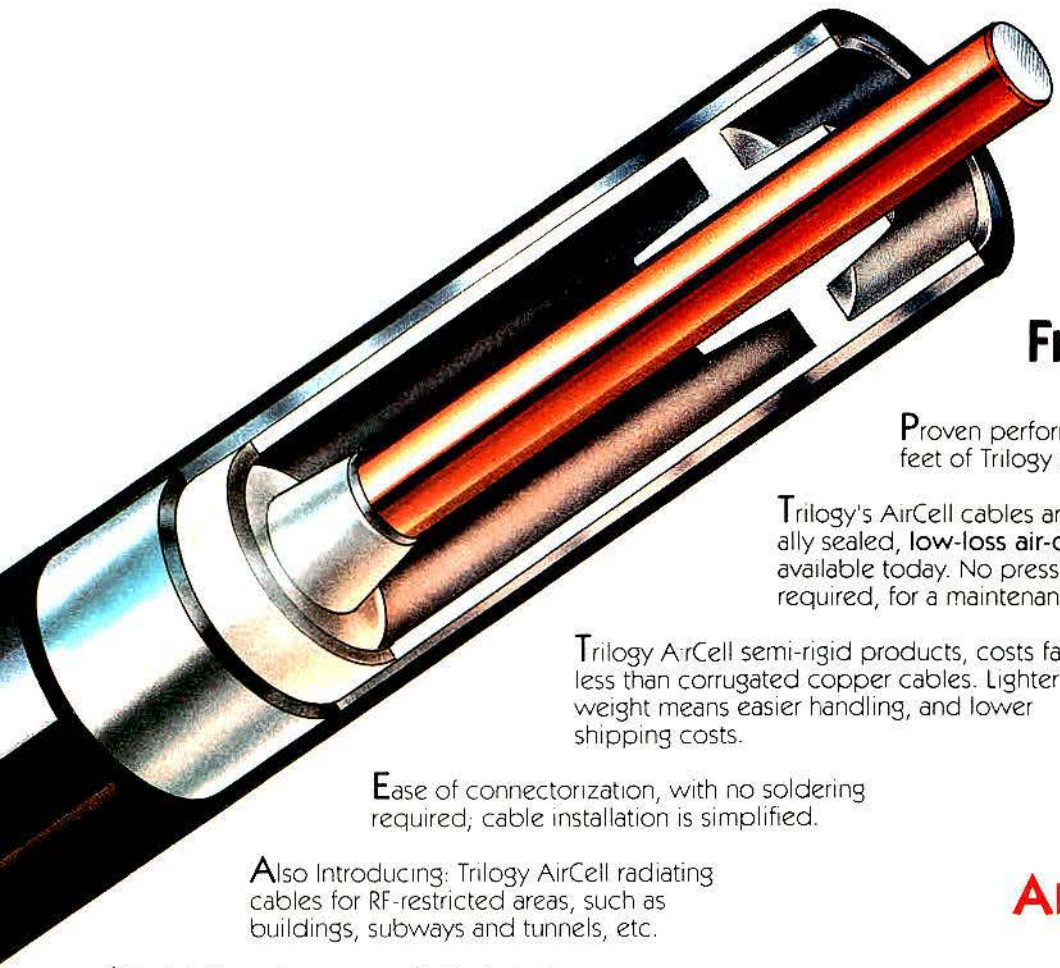

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Choosing the correct antenna gain to meet the subscriber's needs is a logical place to start. There are three basic decibel (dB) gain levels of mobile antennas: quarterwave (or unity gain), 3dB gain and what is commonly referred to as the 5dB gain, which in reality is a 3dB antenna that has been lengthened. (For the sake of identification, 5dB will be used as a point of reference.) Each gain level has a unique radiation pattern and is best suited for a specific application.

Specific applications

▶ *Metropolitan areas* — Because the quarterwave antenna has a maximum radiation pattern that is usually above the horizon, its optimum area of use is generally metropolitan downtown districts and adjacent locations. Typically, these areas are centers of commercial and government offices, and carriers are likely to saturate the area with relatively high signal levels.

Subscribers who spend the vast majority of their mobile talk-time in these areas can use a quarterwave antenna.

▶ *Mixed use* — When in doubt, use a 3dB gain antenna. The 3dB gain is the original antenna designed for cellular phone use and is ideal for subscribers who require high-quality service from downtown to the city limits and out to the suburbs. The 3dB gain antenna's radiation pattern emanates at a vertical angle somewhat lower than the high-angle pattern of the quarterwave and slightly higher than the low-angle pattern emitted by the 5dB gain antenna. This pattern makes the 3dB gain antenna compatible with the typical cell-site configuration and service coverage patterns designed to cover entire metropolitan areas.

A 5dB gain antenna should be the choice for subscribers who will use their mobile phone in rural locations.

Wide-open spaces

A 5dB gain antenna should be the choice for subscribers who will use their mobile phone in rural locations. The antenna's maximum radiation pattern is more compressed, making it best suited to a wide coverage area where cell sites are considerably farther apart than in metropolitan areas. Users who limit their need for mobile communications to such places as a farm or ranch, or those who require service as they travel interstate highways, are prime candidates for a higher gain antenna.

Mounting basics

For an antenna to function properly, it must be installed in a location on the vehicle where it will have the most exposure to the radio frequency (RF) signals from cell sites in the coverage area. Maximum exposure is achieved only when the antenna's whip projects above the vehicle's roof line. Mounting the antenna with the whip rising above the roof prevents the vehicle from blocking, distorting or shading the RF signals and ensures a strong, clear connection.

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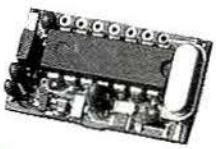

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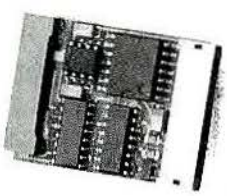

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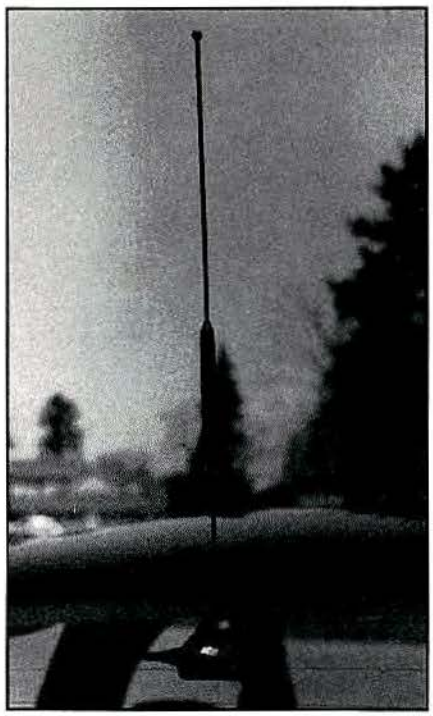

The glass-mount antenna whip should be above the roof line, and the base should clear defogger wires and the wiper.

Different mounting types of antennas offer different advantages and challenges. Excluding the temporary magnetic and window-clip mounts, the three primary categories of antennas are the roof-mount, trunk-mount and glass-mount.

Straight to the top

Roof-mount antennas offer the obvious answer to installing the antenna so the whip is above the vehicle's roof line. By going straight to the top, the antenna is removed from any possible interference from the vehicle, and it can reach its designed performance level.

A roof-mount antenna is designed to be used on a vehicle with a metal roof. The roof becomes a part of the antenna because it acts as a ground plane. This ground-plane requirement prohibits the installation of roof-mount on convertibles or on vehicles with a fiberglass or plastic body. Particularly with convertibles, some inexperienced installers may try working around this limitation by installing a roof-mount antenna on the vehicle's trunk or rear bumper. This position places the antenna's whip well below the roof line and impedes its effectiveness.

Some subscribers may not want a roof-mount antenna because of the hole in the roof required to connect the cable to the mobile phone. With many subscribers mindful of the vehicle's resale value or the terms of their lease, the hole-mount antenna may not be a suitable option.

One other consideration must be made before installing a roof-mount antenna: the clearance of the subscriber's garage door.

Avoiding ground plane limitations

To get around the roof-mount antenna's ground-plane requirement, a ground plane-independent, elevated-feed antenna was developed. (*Feed*, short for *feedpoint*, refers to the point where the cable—the *feedline*—attaches to the antenna.) Designed for a vehicle's trunk, fender or bumper, the tall, elevated-feed antenna operates independently of a ground plane, and, therefore, can be placed on a fiberglass or plastic vehicle. Its length places the whip above the roof line.

Some trunk-mount antennas are designed for the trunk lip and feature clip-on installation. This configuration eliminates the need to drill a hole in the vehicle and allows the user to detach the antenna and place it

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in the trunk when the vehicle is not in use.

The popular choice

Since its introduction into the cellular market in 1983, the most popular mobile antenna among subscribers has been the glass-mount. Last year it outsold the roof-mount and trunk-mount antennas by about three-to-one.

There are a number of reasons for the popularity of the glass-mount antenna. One is that it does not require a ground plane; therefore, drilling a hole during installation is not necessary. The glass-mount antenna protects the vehicle's resale value and does not violate terms of a lease. Glass-mount antennas are also relatively easy to remove and to reinstall when the subscriber gets a new vehicle. Another reason for their popularity is that most users find the glass-mount more aesthetically pleasing than either the roof-mount or trunk-mount antennas. Because a glass-mount typically is mounted on the rear windshield, it is less conspicuous than its counterparts.

Installers must take care to place the glass-mount high enough on the windshield so the largest portion of the antenna's whip is above the roof line. Whether on the front or rear windshield, the antenna should be at least one-fourth of an inch from the path of the windshield wipers. Defogger wires and metal-based window tinting also must be taken into consideration during installation. A window test kit can alleviate any concerns about proper installation.

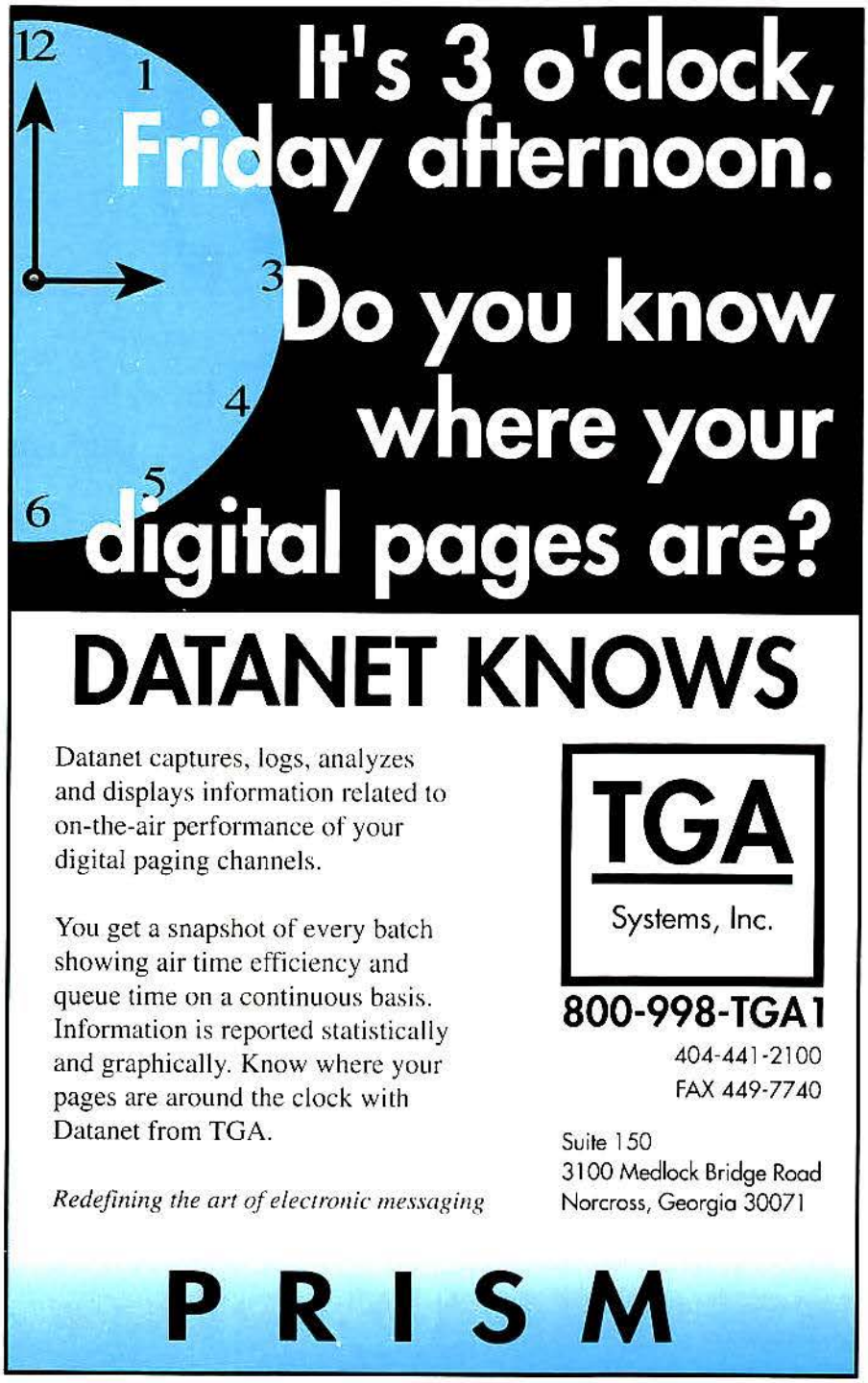
'Solid-state of the art'

A glass-mount antenna with a solid-state coupling box combines the advantages of a mount that does not require a hole, an antenna with 3dB gain and a configuration with mechanical strength. Designed and produced by my employer, the antenna was introduced in 1993.

There are no moving parts inside the solid-state coupling box. This virtually eliminates mechanical failure because the antenna is not prone to long-term degradation caused by vehicle vibration. The antenna, with a typical voltage standing wave ratio (VSWR) of 1.5:1 across the entire cellular frequency spectrum, provides a better transfer of signal to and from the transceiver than an antenna with a 1.9:1 VSWR. The lower VSWR provides a stronger RF signal and reduces the possibility of interference with the vehicle's electrical system and onboard computer. The solid-state coupling box is smaller—by about 50%—than those of other glass-mount antennas and fits between defogger wires, dispelling any concerns of electrical interference. Solid-state construction also precludes the need for field-tuning the antenna during installation because the coupling box is factory-tuned.

Competitive edge

With the number of cellular service subscribers growing every day, competition between carriers to attract and keep new users is fierce. With every new subscriber gained, a carrier invests an average of more than $600 in technology, advertising and incentives. To protect that investment, carriers and dealers must make every effort to meet the customer's expectations of cellular service by providing the clearest, most reliable connection a subscriber can experience. Cutting corners with the most critical link in the phone installation can stack the deck against a carrier in the high stakes game of providing continual growth of the subscriber base.



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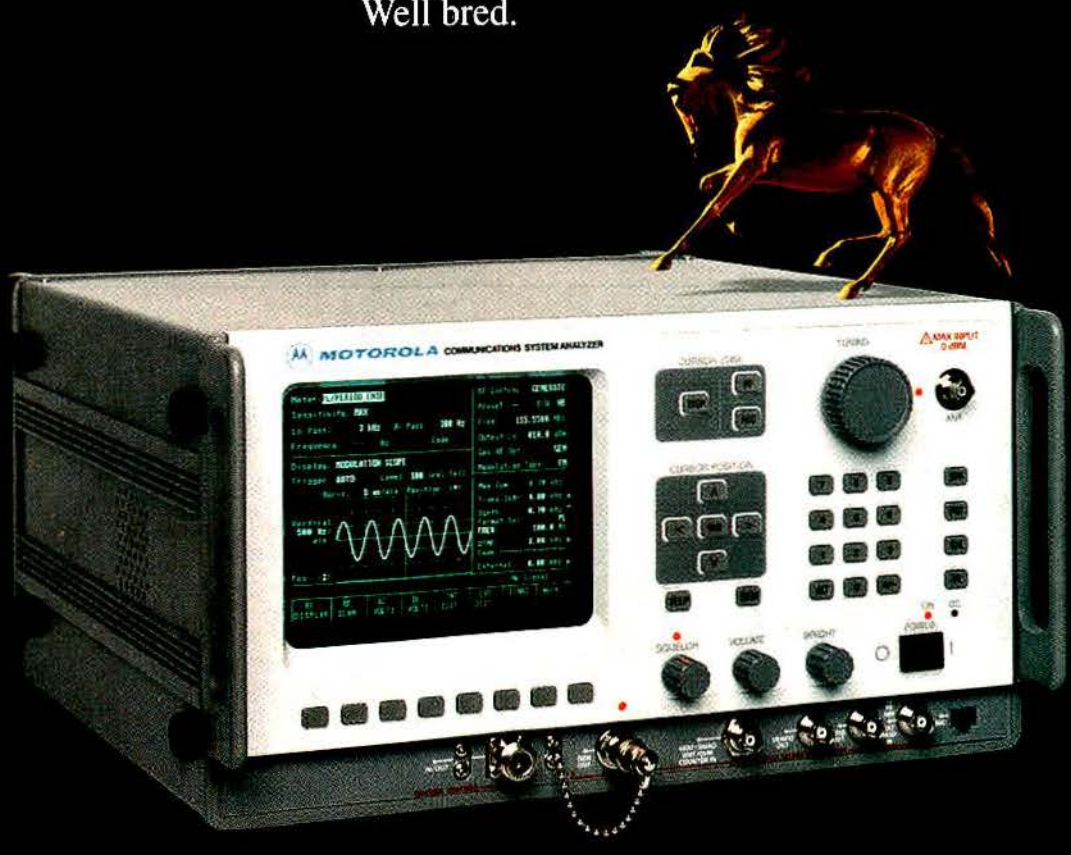

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Circle (15) on Fast Fact Card

Servicing pagers: Elegant simplicity

Part 6—Here are some details about the Bravo receiver circuitry. Surprisingly, the Bravo does not include one particular circuit that is common to most FM receivers. Alignment information is included.

By David Ludvigson

In engineering terms, the Bravo receivers share *elegant simplicity*.

To manufacture a receiver with the frequency stability, sensitivity, selectivity and features found on just the 930MHz Bravo—and to do it with only five transistors and a silicon chip—well, that (for me) defines *elegant simplicity*.

Let's take a look at the Bravo receivers, starting with the NRF series (929MHz–932MHz).

Figure 1 below is a block diagram of one of the NRF series receivers.

Ludvigson is a technician in Houston.

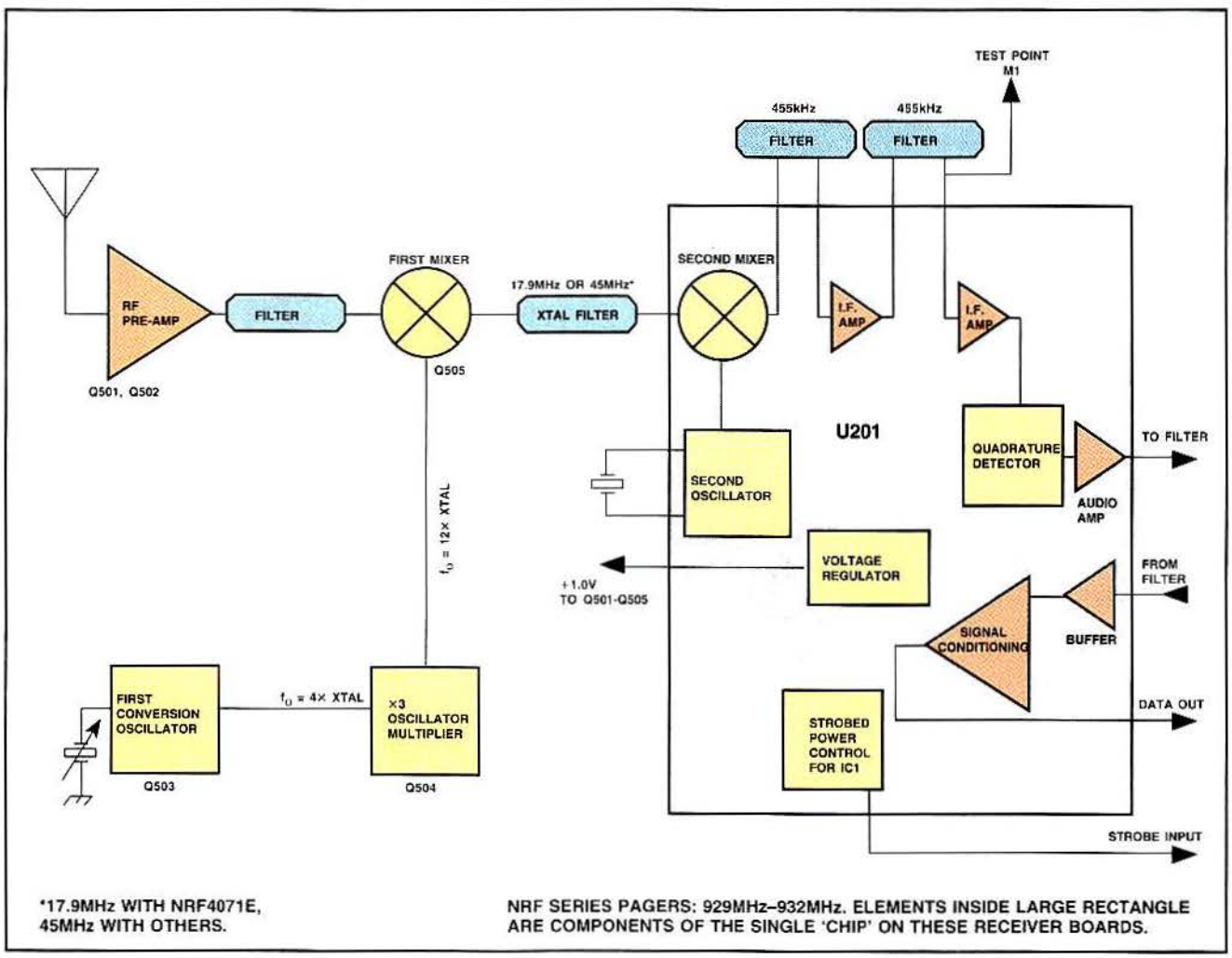
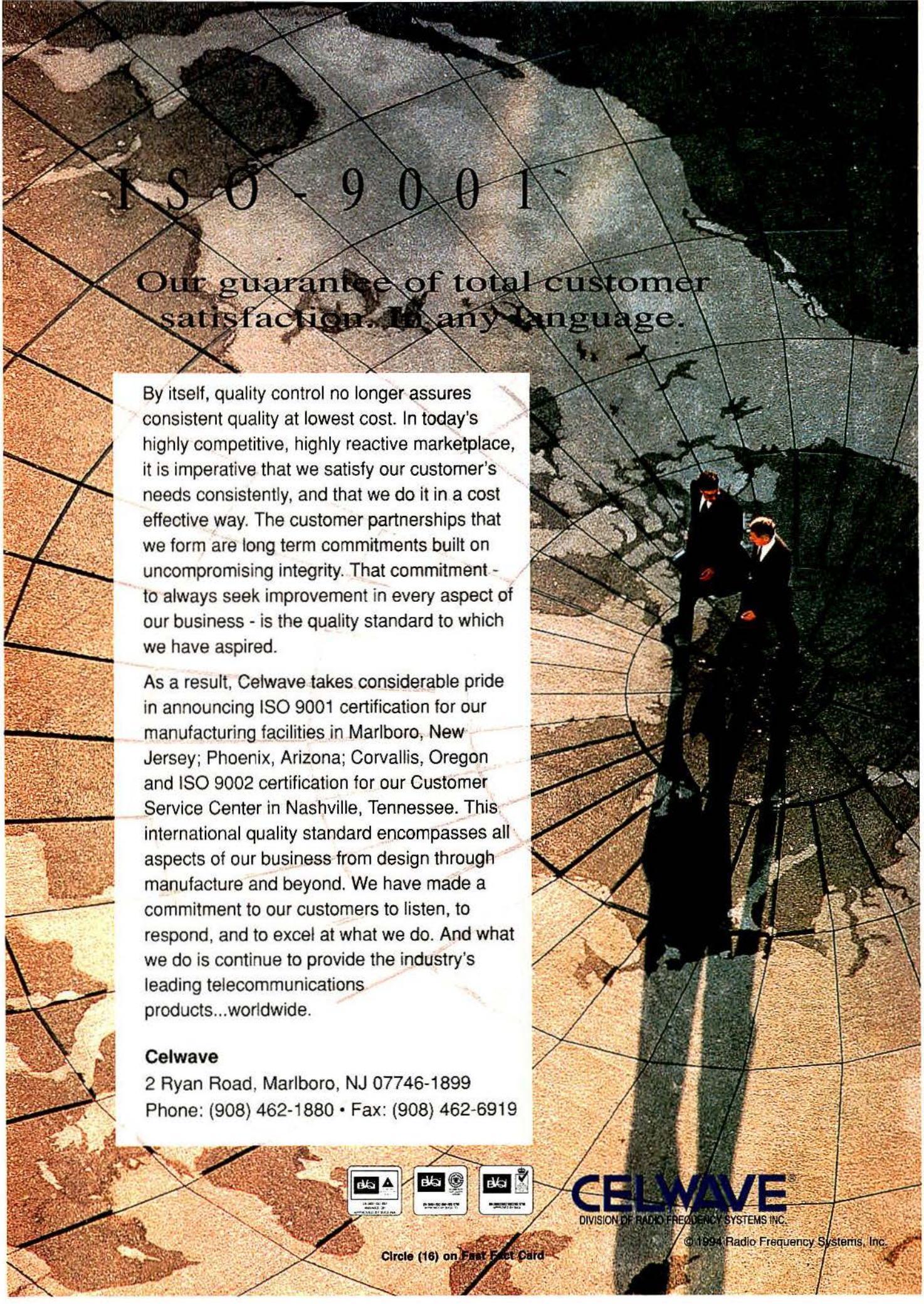


Figure 1. A block diagram of the NRF4071A receiver.



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Circle (16) on Fast Fact Card

Alignment procedure: Bravo NRF series (45MHz IF)

The following procedure deviates somewhat from the suggested Motorola technique and assumes the use of a shielded room (See Part 1) and the IFFER (See Part 2).

1. Set signal generator to exact frequency of receiver: F_{oper} = (12 × 1st conv. xtal) + 45MHz.
2. Frequency-modulate the signal with a 4.5kHz-deviated 1kHz tone.
3. Meter M1 using the IFFER and an oscilloscope.
4. Adjust L511 for a close approximation of a sine wave (as viewed on scope). This should be the first peak as L511 is adjusted clockwise as viewed from the foil side of the circuit board.
5. Trim C521 to slightly distort the signal viewed in step 4. This adjustment affects the multiplier stage and causes "pulling" of the crystal oscillator.
6. Reduce the signal generator's output level. Adjust C521 (multiplier), C532 (45MHz filter response), C513 (930MHz bandpass filter input) and C502 (antenna trimmer)—in that order—to achieve maximum sensitivity.
7. Repeat step 6 as needed for maximum sensitivity. Output from the signal generator should read −90.2dBm (<7μV) for 1,200 baud POCSAG or −92.5dBm (<5.5μV) for 512 baud POCSAG. Measurements are signal generator output level readings applied through a 6dB attenuator to the RTL-1005 fixture.

(Additional detail is available from the schematic printed in the pager manual.) The antenna loop circuit (L501 and L502) is coupled via L503 and L504 into the emitter of Q501. C502 provides antenna tuning for the frequency of interest. Between the loop antenna and the emitter of Q501 is a matching network that effectively transforms the high-impedance antenna to about 50Ω. Q501 and Q502 provide roughly 12dB–15dB of signal gain.

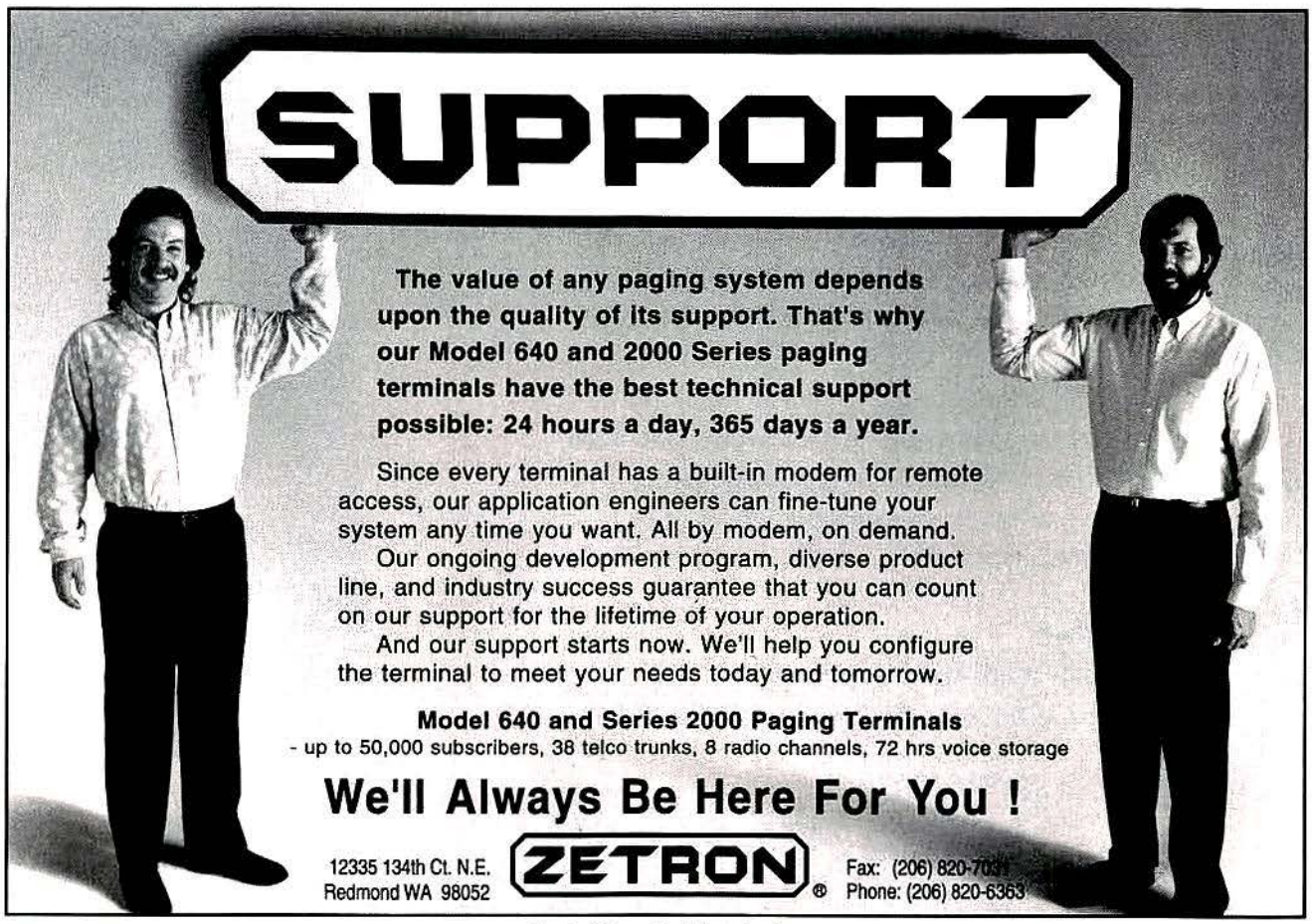
Configured in *common base*, these transistors' input and output signals remain *in phase* with each other, making neutralization virtually unnecessary. Output from Q502 (L508, C512 and C513) is tuned to the input frequency, reducing adjacent channel signals and images by about 15dB.

Lightly coupled by C514, this stage easily matches the 50Ω stripline filter (FL501).

FL501 is the "postage-stamp" near the first-conversion oscillator crystal on these boards. This dual-pole stripline filter has been pre-assembled and pre-tuned to provide image signal rejection at around 840MHz, while passing the 929MHz–932MHz antenna signal.

In the meantime, a signal is being generated at the first conversion oscillator. Q503 is a basic Colpitts oscillator operating from a nominal 73.8MHz crystal. The collector circuit of Q503 is roughly resonant at a frequency four times that of the original 73.8MHz, thus providing a frequency of 295.2MHz—along with the strong presence of 73MHz—to the base of Q504.

Between the collector of Q503 and the



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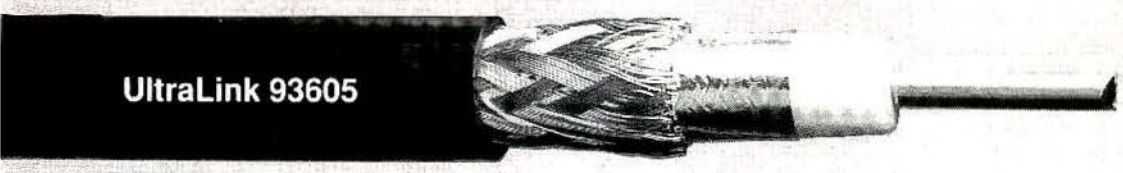

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base of Q504 is a network (L514, C521 and C520) that is tuned to the 4th harmonic of 73.8MHz (295.2MHz). Having cleaned up the input, Q504 is used as a frequency tripler to provide an output of 12 × 73.8 = 885.6MHz.

Q504's collector is broadly tuned to 880MHz by the combination of C524 and L515. Note the use of resistor R508, though. This resistor lessens the effective "Q" of the tuned circuit, allowing a fair amount of multiplier bandwidth.

L516 and C526 may seem redundant, but actually they provide another filter that keeps the output signal sinusoidal. (Multiplier stages get messy around the edges of their transition from F_{in} to F_{out}).

So, at one end of the bandpass filter (FL501) there is an amplified off-the-air signal, and at the other end of the filter the first conversion oscillator signal is injected. Mixer Q505 helps to sort them out.

At the base of Q505 is a parallel resonant circuit (C529 and L517) that closely matches the frequency response of the bandpass filter FL501. It also provides image rejection by selectively reducing the first conversion oscillator signal and passing the antenna signal.

Q505 mixes the incoming antenna signal at 930.6MHz with the signal frequency of the first conversion oscillator (at 885.6MHz) to provide an output of 45MHz.

The incoming FM signal should be deviated from 4kHz to 5kHz by the data stream. (Years ago, 5kHz deviation was the norm, but today the maximum deviation seems to vary.) As such, the second conversion mixer output should be able to pass at least ±5kHz from the center frequency. Bravo pagers' second conversion mixers pass signals with deviation from ±3.5kHz to ±5kHz, depending on the crystal filter's frequency.

The 45MHz intermediate signal then is mixed at the "crossed circle" located in IC U201. Onboard U201 is the "second oscillator," with C026 coupling either the 44.545MHz or 45.455MHz signal back to the second mixer.

Mixer output goes directly to a narrow-bandwidth external 455kHz filter, back into the chip for amplification, and into another filter. The second filter's output is test point M1 and the input to a second IF amplifier.

Up to this point, old-timers will have noted something *strange* about the entire receiver. *There is no limiter circuitry in it,* nothing to prevent it from responding to an AM signal, a dead carrier or a single-sideband signal. In short, it "pays attention" to anything it hears.

It is only after the second 455kHz amplifier that the "whatever it hears" is demodulated by an active quadrature demodulator, and we have an actual FM receiver. Demodulator output is sent to low-pass filter and audio buffer stages, and subsequent RC filtering networks on the decoder board.

Once filtered, the audio signal is processed further by the peak and valley detectors, limited, and then returned to the decoder board as *data.*

Further refinements in U201 include a battery-check comparator with a *1* or *0* output at TP9, and a voltage regulator with 1V output for all five transistors on the receiver board. The *main current reference* is toggled later by the *battery saver signal,* but it may be defeated by forward-biasing TP10 with a 10K resistor fed from TP4.

Elegantly simple, or simply elegant. A 930MHz receiver that fits in the palm of the hand, and is run by a 1.5V battery.

Acknowledgement

I would like to thank J.H. Kim, owner of JJ Sounds, South Houston, TX, and coworkers Raymond, Tim and Pete, for their help with this project.

Pager servicing series

Part 1: "Build a Shielded Room," January 1994.
Part 2: "Build An 'IFFER,'" February 1994.
Part 3: "Frequencies, Coding Formats," March 1994.
Part 4: "From Bench To Programmer," April 1994.
Part 5: "The Receivers," May 1994.
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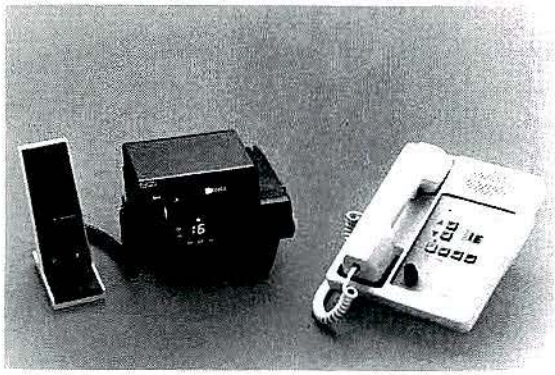

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Rechargeable batteries: lead-acid and lithium

Part 2—To help you choose the right battery for your application, the pros and cons of four types of batteries: nickel-cadmium, nickel-metal hydride, sealed lead-acid and lithium polymer, are compared.

By Isidor Buchmann

Last month's installment explained the most popular battery for portable radio communications equipment, the nickel-cadmium (NiCd), and its challenger, the nickel-metal hydride (NiMH).

Other types of battery chemistries have advantages to offer in certain applications.

Lead-acid battery

Another commonly used battery is the lead-acid type.

The *flooded* version is found in automobiles.

We will examine the *sealed* lead-acid (SLA) battery.

The SLA is commonly used when high power is required, weight is not critical and cost must be kept low. The typical current range of the SLA is 2Ah to 30Ah.

Applications that fall into this category are wheel chairs, uninterruptible power supply (UPS) units and emergency lighting. There are also some transportable cellular phones, laptop computers and camcorders that use SLA batteries.

During the '80s, the SLA gained ground in the bio-medical industry. Today's bio-medical instruments are powered by about 60% SLA and 40% NiCd batteries.

The SLA is not subject to memory. No harm is done by leaving the battery on trickle or float charge for a prolonged time. If removed from the charger, the SLA retains the charge for a longer period than the NiCd and NiMH. The SLA is usually lower-priced per Ah than other rechargeable batteries.

On the negative side, the SLA does not lend itself well to fast charging. Typical charge times are eight hours to 16 hours.

The SLA always must be stored in a charged state. A discharged SLA *sulphates* within hours. If left in that condition, a recharge is difficult or impossible. A problem would arise if no charger were available, for example, when filming in the Sahara Desert or when calling from a cellular phone while crossing the Antarctic.

Unlike the NiCd, the SLA prefers a shallow discharge. A full discharge causes extra strain and reduces the cycle count. The number of discharge-charge cycles in the lifetime of an SLA is 200 to 300.

An additional difficulty of the SLA is a relatively low discharge current. The amount of current that can be drawn is further reduced at lower temperatures.

Compared to other rechargeables, the energy density is low, making the SLA unsuitable for cellular phones and other devices that demand small size. Because of its high lead content, the SLA is not environmentally friendly.

Rechargeable lithium battery

The rechargeable lithium battery is the most talked-about battery chemistry in research labs today.

What makes this battery so exciting? One of the biggest advantages of the lithium battery is its high energy density. Indeed, the lithium weighs less than half of the equivalent NiCd. Equally exciting is the fact that once charged, the lithium retains its energy for as many as 10 years.

The lithium has several of the same negative characteristics as the SLA, though. Charge times are a long eight hours to 16 hours, and the discharge current must be kept low. The cycle count is only 150 to 300 and is related to the depth of discharge.

The rechargeable lithium battery is fairly expensive and is likely to continue to cost more than its rivals.

Disposal may cause some problems. The concern is not its toxic metal content but the danger of explosion during corrosion as a direct result of exposure to moisture.

On earlier versions of rechargeable lithium batteries, stability was a major concern. This difficulty supposedly has been solved with the use of a solid-lithium polymer. Battery experts speculate that it will take another three to five years before

Table 1—Battery chemistry comparison.

	NiCd	NiMH	Lead Acid (sealed)	Lithium Polymer
Energy Density (Wh/kg)	55	70	35	175
Cycle Life (typical)	1500	500	200-300	150-300
Fast-charge time	1½h	2-3h	8-15h	8-15h
Self-discharge	moderate	high	low	very low
Cell-voltage (nominal)	1.25V	1.25V	2V	2.8V
Peak discharge current	high	moderate	moderate	low
Cost	low	moderate	low	high

Buchmann is the founder and chief executive officer of Cadex Electronics in Burnaby, British Columbia. He has been active in the radio communications sector and has studied the behavior of NiCd batteries in practical, everyday applications.

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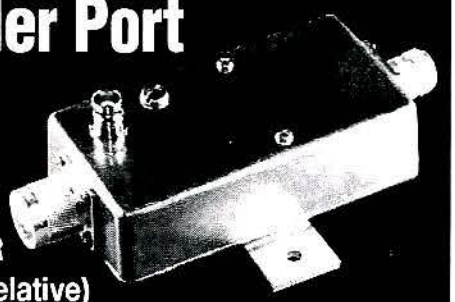

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the rechargeable lithium battery will be readily available.

Battery chemistry comparison

When selecting a battery, equipment design engineers consider energy density, cycle life and cost.

Table 1 on page 24 compares the pros and cons of four types of batteries: NiCd, NiMH, SLA and lithium polymer. The energy density is measured in watt-hours per kilogram (Wh/kg).

The cycle life is based, in part, on the depth of discharge and how the battery is maintained. Corresponding figures in Table 1 reflect the number of charge-discharge cycles applied until the battery capacity has decreased from 100% to 80%. Fast-charge time refers to cells that are rated for fast charging.

During the past 30 years, the rechargeable battery's capacity for a given size has not improved much.

Compared to advancements in microelectronics, battery technology lags.

Compared to advancements in microelectronics, battery technology lags. Take, for example, a computer memory core of the '60s that measured one cubic foot in size and compare it to a modern microchip of the same byte count.

Applying this size reduction to a battery would literally shrink a heavy-duty car battery to the size of an apple seed! Because today's batteries still are based on a chemical process, the availability of a battery of the size of an apple seed that can start a car may still be some time off.

Next: Memory effect and self-discharge; and battery conditioning.

Rechargeable battery series

The previous installment in this article series is "Rechargeable Batteries: NiCd and Nickel-Metal Hydride" in the May 1994 issue.

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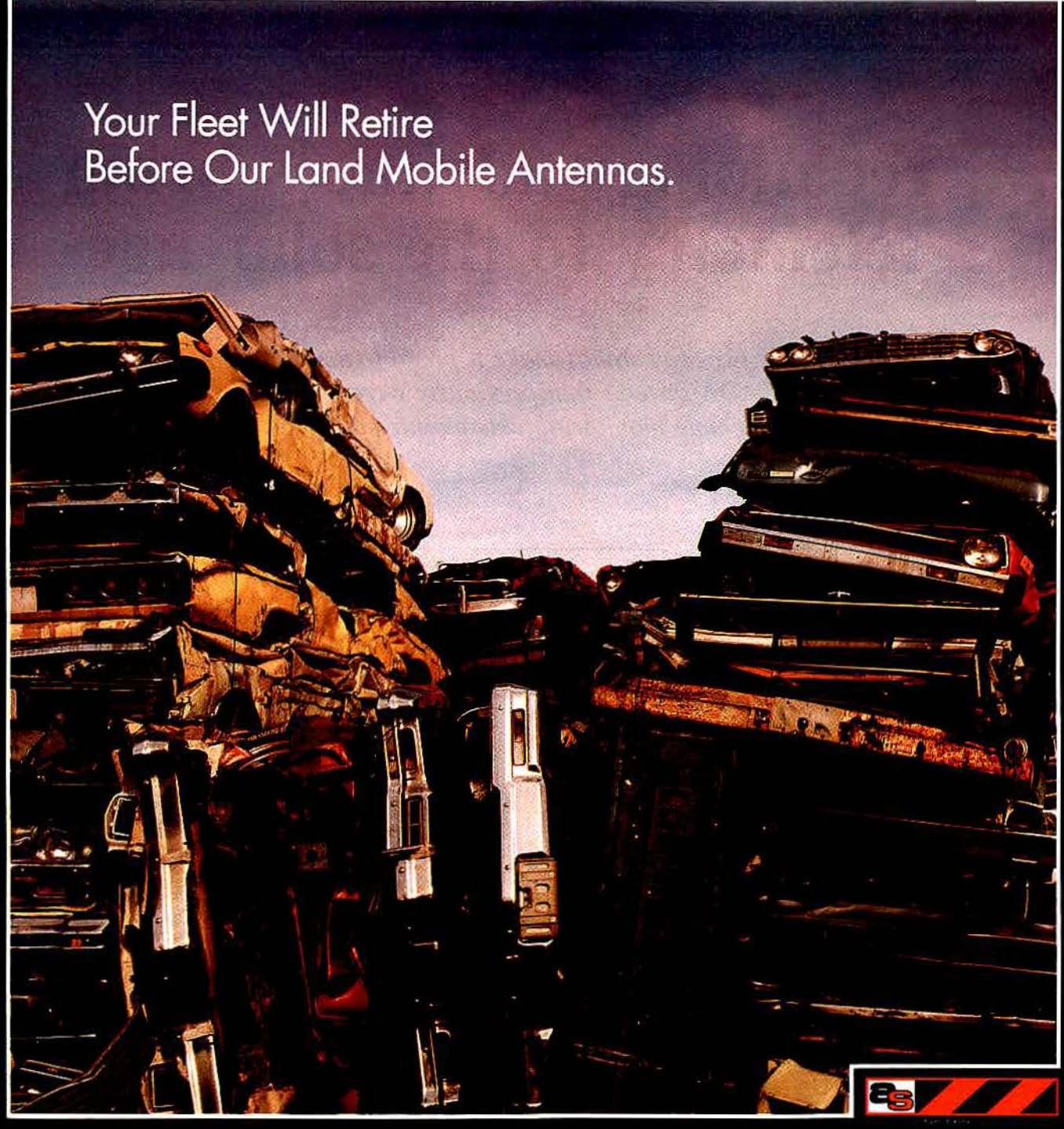

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Technology advances bring telemetry to the solar age

Solar panels and two-way radios make it possible to equip remote sites with telemetry and SCADA systems that previously were too expensive to monitor. Remote monitoring cuts maintenance costs.

By Jack Robert

For many years, the relatively high energy requirements of computers and communications links limited the use of telemetry and supervisory control and data acquisition (SCADA) systems in monitoring and controlling electrical distribution, especially at remote locations.

Advances in portable computer and radio equipment designs that reduce their energy requirements now allow solar power supplies to be used in remote locations that previously were too expensive to outfit with telemetry and SCADA systems.

Early mechanical SCADA and telemetry systems were cumbersome and expensive. Barely 15 years ago, industrial electronic equipment used 120Vac or 240Vac power exclusively. Now, 5V logic circuits are common, and it is possible to power a SCADA or telemetry system with a 6V or 12V battery.

Not long ago, most SCADA and telemetry systems were placed only where telephone lines reached. Today's two-way radios and cellular telephones support telemetry systems at isolated sites where telephone line installation is too expensive.

A typical telemetry system is housed in a weatherproof enclosure. It consists of a remote terminal unit, power supply, battery, radio and antenna. Including a solar panel, a regulator and a good deep-cycle battery can make such systems self-sustaining for years on end.

Portable computers

As anyone who has used an early portable computer knows, the weakest link in its operation was the power supply. The plain truth is that the units were energy hogs. If you planned on working extensively on dc power, you had to carry so many battery packs that your portable computer became nonportable.

Portable computer developers reduced integrated circuit (IC) operating voltages from the earlier 12V, 9V or 6V to the 3.3V logic that is typical today. Although the primary purpose of the voltage reduction was to reduce the heat generated by laptop computers, another benefit is extended battery life—and an entirely new level of convenience.

The low-voltage microprocessor technology gave birth to a new generation of less expensive, more efficient and more durable industrial electronic devices, including telemetry systems.

Radio equipment reflects the progress made in the computing industry, too. Data radios, for example, can reside in a "sleep mode" that uses almost no current until the unit is activated to deliver a message. An event "wakes up" the radio just long enough to send a data burst that may last a second or less, compared to the multiple seconds (and associated power drain) required to transmit a voice message. As a result of these multiple innovations, "wireless" telemetry applications are being welcomed in more and more industries, including electricity transmission and distribution companies.

The concepts of SCADA and telemetry systems have been around since it first occurred to someone that monitoring and reacting to remote events from a central location might be cheaper than keeping service crews on patrol to track routine industrial activities. Such systems save large sums of money by reducing unproductive maintenance and monitoring time, by pinpointing problems quickly, and by dispatching repair or maintenance crews more efficiently.

Many electric utilities use telemetry to track and to control activities at substations, automated circuit breakers and other crucial points in the transmission and distribution system. Typical applications include operations as simple as reporting and reacting to a breaker's open-or-closed status or reporting malfunctions down the line. Other agencies use telemetry to collect data over an extended period to compile performance reports and to schedule maintenance activities.

What's in it

In an electric utility, these wireless telemetry systems usually consist of one or more transducers (to monitor voltage and current), electronic circuits that convert transducer signals into data signals, a re-

Robert is editor of *Advantage*, a newsletter published by Zetron, Redmond, WA. He has written articles for technical publications about aviation, aerospace, telephony, public safety, electronics and software for scientific, business and engineering applications.

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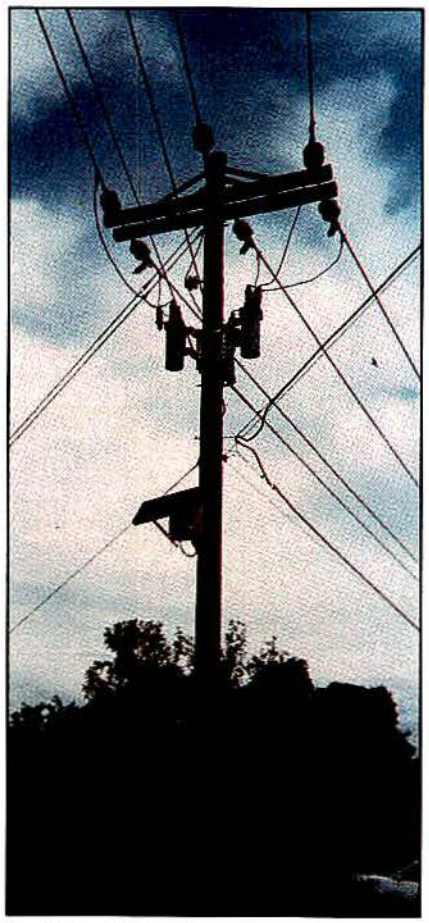
mote terminal unit (RTU) to convert data into a digital element for transmission, and a two-way radio to send the message and to receive the response.

At the other end of the wireless route is a radio that receives the digitized message and a control device that converts the data into a form that can, in turn, be interpreted by the central personal computer (PC). Where a response is in order, the computer receives and reacts to the message, and then transmits a command (open or close the breaker, for example) back to the site along the same route.

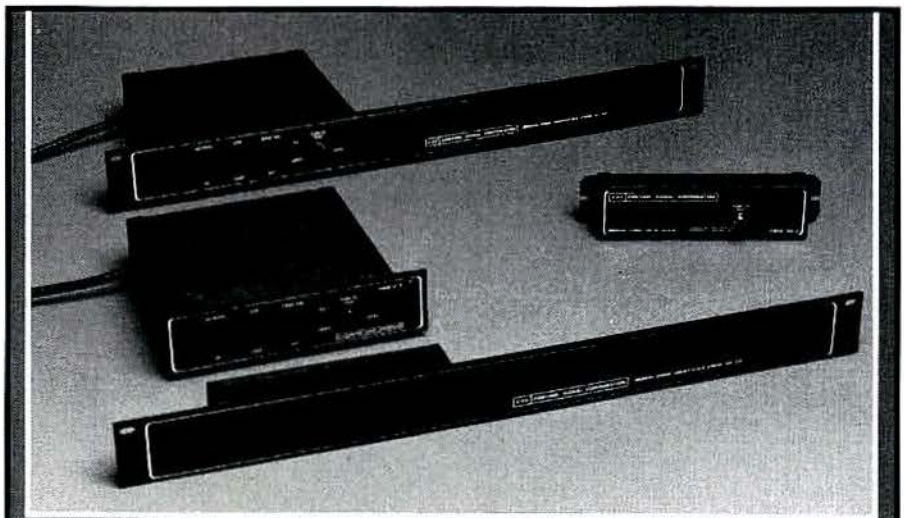
These modern systems have enjoyed an excellent reputation in a wide range of industrial applications for more than a decade. The good news is that they typically are self-contained, powered by a long-life battery. The bad news is that the world's finest battery will not last forever. Fortunately, when a photovoltaic (solar-electric) charging system is added, the telemetry system becomes virtually self-sustaining.

So says Sam Calder, a communications and instrumentation technician at Guadalupe Valley Electric Cooperative (GVEC), which delivers power to more than 30,000 billed customers over an expansive four-county region not far from San Antonio, TX. GVEC uses 20 electrical substations and 4,898 miles of line to deliver power. The cooperative uses a SCADA and load management system for detecting and reacting to problems on its electrical distribution system and to control the system load.

According to Calder, solar-powered RTUs have been placed in strategic locations down the line from substations to monitor automated breakers. "We can now see how often the breakers open and close and identify any behavior patterns that might indicate a malfunction trend," he said. The system collects exception reports (breakers tripped, for example), as well as data generated by polling the entire net-



Guadalupe Valley Electric Cooperative has placed solar-charged remote terminal units (such as this one) downline from substations to monitor automated breakers.



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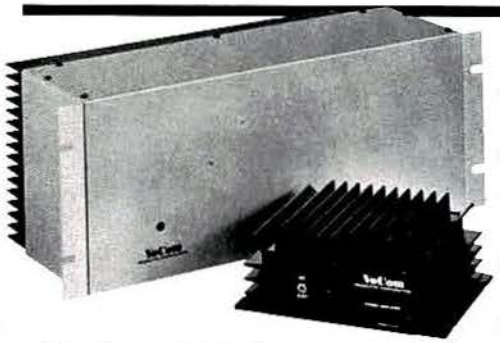

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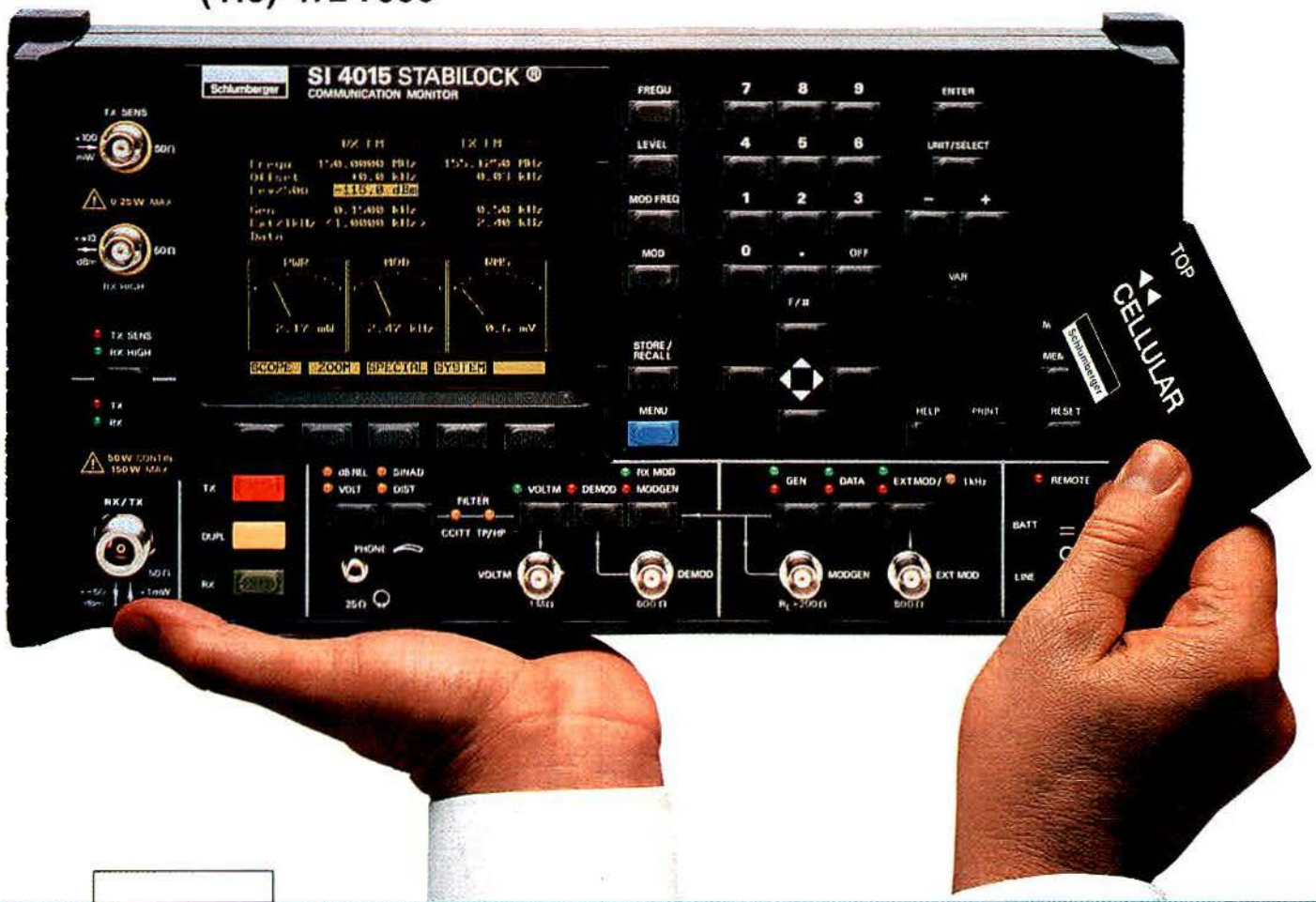

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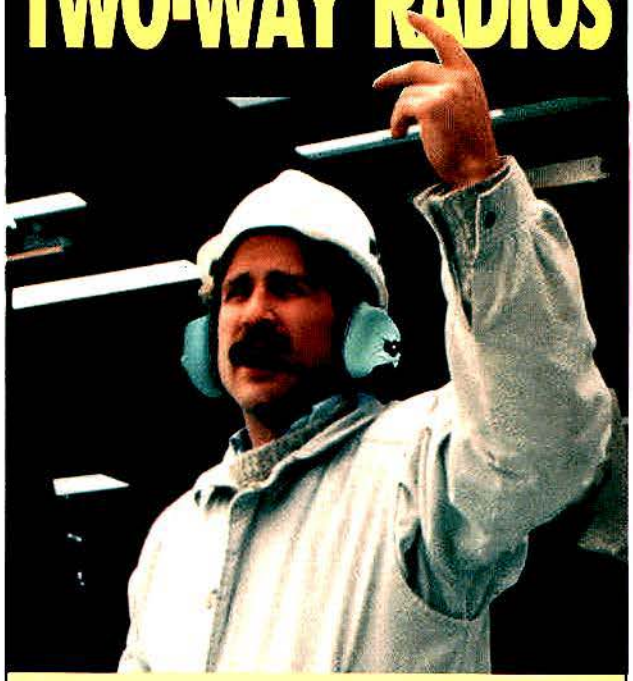

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Putting a solar system together

Solar power is a logical, cost-effective way to power remote systems, particularly where *remote* is the operative word. A solar panel, battery charge regulator and a 12V deep-cycle battery can be installed virtually anywhere for a fraction of the cost of providing a conventional power source, particularly where the RTU is extremely isolated. A little advance study and a few calculations are all you need to put together a solar-operated monitor and control system. (See Figure 1 below.)

The electronics vary with the application. For substation security (such as "unauthorized entry" messages) or breaker open-or-closed status, typical RTUs such as Zetron's models 1708 or 1716 are effective. However, for measuring current, extremely high voltages and other physical characteristics, a measuring device consisting of a transducer and associated electronics is also required. A little care must go into specifying the configuration, but once the system is in place, it offers relatively trouble-free, self-sustaining operation. To determine your requirements, follow these steps.

(1) Calculate the daily power usage required. Let's assume that there will be nine transmissions per day, including two "all clear" messages. The rest of the time, the RTU is in monitor mode, and the radio is in receive mode, thereby minimizing power consumption. Total consumption on an average configuration with transducers, 1708 RTU, 2W radios and a charger is about 4Ah per day, although it will vary with the type of radio and other equipment used.

(2) Determine the solar panel output requirements. The panel must provide enough power to drive the electronics and to keep the battery charged. It is important to select a panel that provides adequate power even in worst-case sunlight conditions. (A solar map provides this information.) In addition, the calculation must take into account dust accumulation, unexpected shading and other hostile conditions. Adding 20% to the figured output should cover these conditions.

(3) Select a battery. Typically, the battery should have the capacity to sustain the system for three days to 20 days without sunlight, depending on the region. For the average configuration as described in Step 1, total discharge for the period is 68Ah. However, the battery's capacity also should be adequate to compensate for local temperature extremes. For example, at –20°C, a lead-acid battery functions at only 65% of its rated capacity. To ensure that the battery functions appropriately in absolute worst-case conditions (where both temperature and surface accumulations deteriorate performance), a 100Ah battery is required. Again, most batteries designed specifically for deep-cycle applications meet the criteria.

(4) Select a solar regulator. It should have a compensation circuit that adjusts the charging voltage in accordance with changing temperatures. A suitable voltage regulator can control 4A–8A within a range of 13.2Vdc–14.5Vdc.

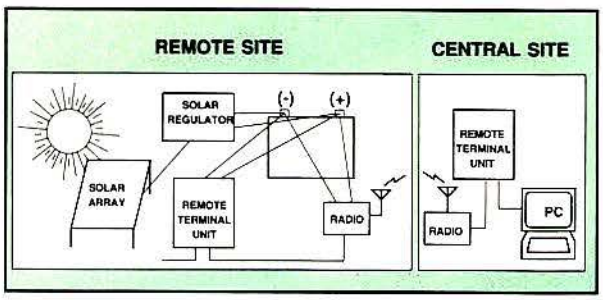
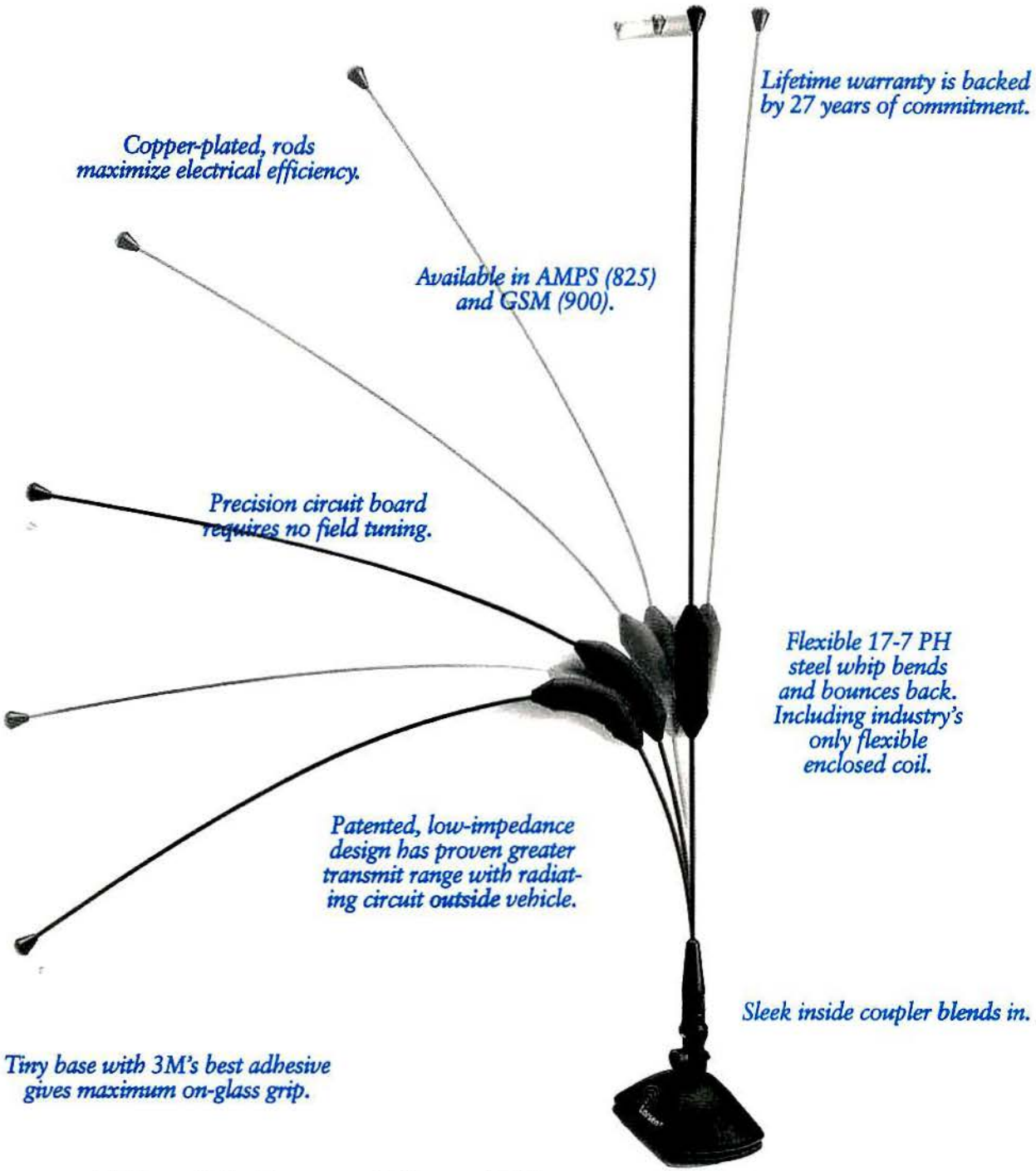


Figure 1. An isolated remote terminal unit can be powered by a solar panel, battery charge regulator and a 12V deep-cycle battery for a fraction of the cost of conventional power.



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work at half-hour intervals.

Calder said that a primary benefit of the telemetry system (without regard to a particular unit's power source) is the ability to isolate the problem to a specific stretch of wire. This enables the repair crew to locate faults more quickly. For example, if there is a fault in a certain breaker's area, crews no longer have to search the line in both directions from the breaker to find the problem. "These RTUs tell us which side of the breaker the problem is coming from," said Calder. "That information reduced the search area by 50% from the beginning," he added.

Calder said he is very pleased with the solar-powered units. "We've been able to take the old 'set-it and-forget-it' adage very literally in this case. We've had the units in place for well over a year, and we haven't had to go out to one of those sites for maintenance purposes once. We don't use very big batteries for the units (33Ah–60Ah), but they keep everything running reliably."

Even regions that experience extended periods of cold, darkness or cloud cover can benefit from photovotaic-charged telemetry systems when a suitable wintertime charging system is in place. Entire telemetry systems (including a propane-powered thermoelectric generator) are kept underground in the insulated silo (Equipment is shown being lowered into the silo entrance by the hand winch on the right.) *Photo courtesy of Safety & Emergency Systems, Woodinville, WA.*

Computer technology finds solar applications as well. Bill Rever of Solarex, Frederick, MD, an Amoco division, said that one reason more and more companies are becoming interested in photovoltaic chargers is that the photovoltaic industry, too, has benefited from changes in the computer world. As with computing products, solar panel efficiency has increased dramatically over the years, while prices have decreased in similar proportions.

Rever, who is product manager for polycrystalline silicon products at Solarex, states that the technology has come a long way since the 1950s, when researchers first discovered that a properly doped silicon wafer had photo-electric properties. First used extensively in aerospace applications, solar cells were extremely expensive because they were virtually handmade from

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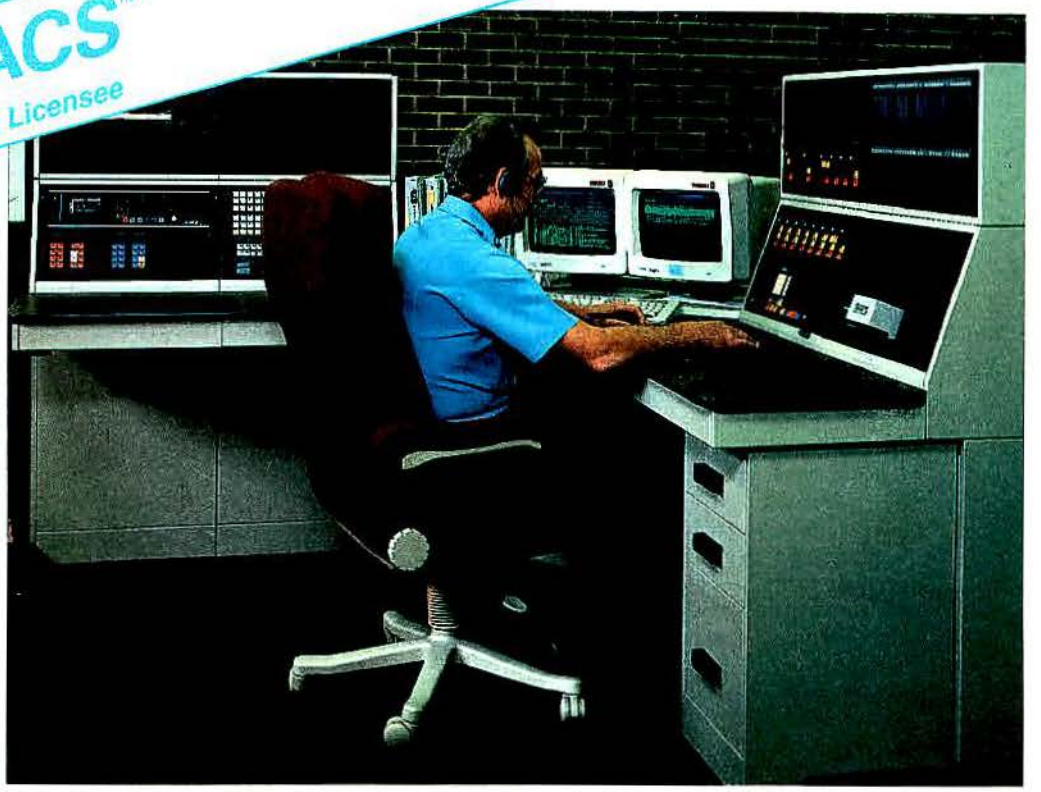

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a single crystal. "When first applied to terrestrial use, the typical 5W–7W panel cost about $200 per watt," Rever said. "All of the units manufactured in a single year generated perhaps 50kW total."

Rever said that attention to the energy crisis starting with the Carter administration gave new life to research, and during that period, solar cell efficiency increased dramatically. (Efficiency is the ratio of energy a cell produces from a given input of solar power; thus, if a solar panel produces 10W of electricity from 100W of solar power, it is 10% efficient.) The average inexpensive panel sold for commercial applications today averages 13%–14% efficiency, which is well within the range required for most telemetry applications.

Smaller, better panels

Several elements directly related to developments in the semiconductor industry also have contributed to the processes that have enhanced the manufacture of solar panels. Of prime importance is the increased availability of purified silicon, the raw material from which solar cells are made. On another front, whereas semiconductors usually are associated with miniaturization, chip manufacturers began demanding *larger* wafers to work with.

The larger boules required enhanced "growing" processes. The larger the surface, the greater the opportunity for blemishes, especially at the periphery. Rever said that after no small amount of experimentation, it became possible to grow an eight-inch diameter monocrystalline boule. The older-generation wafer barely exceeded two inches across. The larger wafers also could be more readily shaped to meet customer requirements.

Several elements directly related to developments in the semiconductor industry also have contributed to the processes that have enhanced the manufacture of solar panels.

Poly crystals

About 10 years ago, companies began developing polycrystalline materials that are commonly used in today's commercial solar panels. In simplistic terms, whereas expensive monocrystalline wafers were grown from a single crystal, polycrystalline products are produced more economically by melting multiple pieces (typically castoffs and scraps from the manufacture of semiconductors) into an ingot.

The polycrystalline product can be cast or cut into precise dimensions (such as squares and rectangles, instead of the necessary circle of earlier-generation panels) and assembled with minimum non-usable space, thereby maximizing the panel's efficiency while minimizing its dimensions. As a result of these improvements, today's average panel typically produces twice the power of a similar-sized panel manufactured a decade ago, said Rever.

Other enhancements include an upper shell of tempered, low-iron glass that

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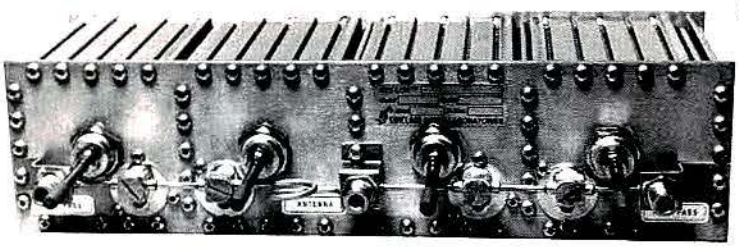

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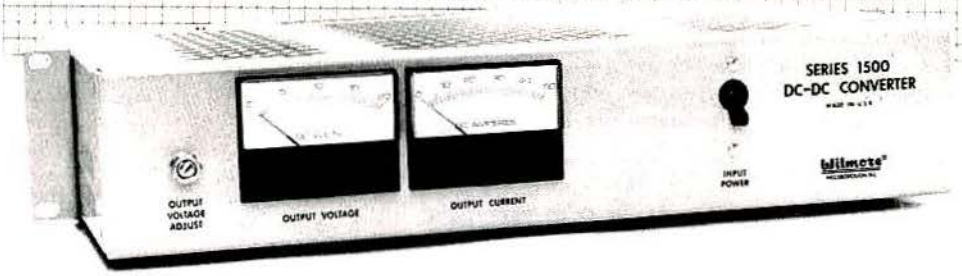

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A combination circuit breaker and ON/OFF switch is provided for the input power. A voltmeter and ammeter display the dc output. A screwdriver-slotted potentiometer shaft with locking nut is provided to adjust the output voltage level.

Size And Weight

All converters measure 3.45" high by 17.0" wide. The 200-watt and 400-watt units are 13.2" deep, and the 800-watt units measure 13.4" deep. All units weigh less than 18 pounds.

Optional Features

Standard options for Series 1500 converters include paralleling diodes for multiple-unit redundancy applications and auxiliary Form C contacts for remote indication of improper converter output. In addition, many other input/output voltage combinations not listed in the adjacent table are available. Contact our sales department for details.

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20-29	12-14	0-30	1502-24-13-30
20-29	22-26	0-8	1502-24-24-8
20-29	22-26	0-16	1502-24-24-16
20-29	44-52	0-4	1502-24-48-4
20-29	44-52	0-8	1502-24-48-8
21-29	45.5-50.5	0-16	1560-24-48-16
40-58	12-14	0-15	1502-48-13-15
40-58	12-14	0-30	1502-48-13-30
40-58	22-26	0-8	1502-48-24-8
40-58	22-26	0-16	1502-48-24-16
42-58	22-26	0-30	1561-48-24-30
42-58	25-29	0-30	1567-48-28-30
40-58	44-52	0-4	1502-48-48-4
40-58	44-52	0-8	1502-48-48-8
40-58	56-64	0-7	1502-48-60-7
40-58	123.5-136.5	0-1.5	1502-48-130-1.5
40-58	123.5-136.5	0-3	1502-48-130-3
42-58	123.5-136.5	0-6	1562-48-130-6
105-140	12-14	0-15	1502-130-13-15
105-140	12-14	0-30	1502-130-13-30
105-140	22-26	0-8	1502-130-24-8
105-140	22-26	0-16	1502-130-24-16
105-140	44-52	0-4	1502-130-48-4
105-140	44-52	0-8	1502-130-48-8
105-140	123.5-136.5	0-1.5	1502-130-130-1.5
105-140	123.5-136.5	0-3	1502-130-130-3

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maximizes solar transmission and has a nontextured outer surface that protects the panel's collector surface from the elements. Thanks to the slickness of the glass and the angled panel positions typically required (to maximize solar input), weather alone (especially wind and precipitation) keeps the surface clean enough to minimize transmission losses, even when the panel is left unattended for years.

Rever added that some customers shied away from the older panels because their small, circular wafers stood out from the framework. "They seemed to challenge that particular minority of hunters that possesses a vandalistic tendency," he said. "Today's panels, with their hidden wafers, aren't nearly as often the targets of vandalism."

Anti-reflective coatings, the encapsulating polymers (to seal and to insulate) and other components have been improved, both to enhance efficiency and to extend the life of the panels. (Rever said the number of dissimilar metals used in the modules—copper interconnects and silver plating—make it imperative that moisture be kept out to prevent galvanic action.) The consequence of these developments, he added, is a solar panel that reputable manufacturers guarantee to stand up to the worst hot, humid climates for 20 years or longer.

World-wide applicability

Although one might equate ideal solar situations with Saharan climes, the potential for solar-powered systems exists almost everywhere, including, believe it or not, in polar regions. Rever said that a thermoelectric generating process is required in areas of extended cold or darkness to keep batteries charged and within operating temperatures. Any solar design consultant can provide a map that plots the total daily solar energy of a given region, a requisite step in specifying a system.

Tag-team champs

The latest generation of solar-powered telemetry systems, according to Joe Swanzy, engineering manager for the Industrial Systems Division at Zetron, Redmond, WA, is a viable system for tracking events at inaccessible locations. "A few years ago, power was a big concern. Even battery-driven telemetry systems needed a lot of attention because of the power consumption.

Today, because the radio and RTU both draw less power, these systems are phenomenally efficient. Add to that the enhanced photovoltaic charging system consisting of a solar panel, a voltage regulator and a few other components, and you have a battery-driven unit that can operate unattended virtually indefinitely."

Swanzy, who has helped a number of companies implement solar-powered systems, explained that a solar panel need only produce about a tenth of the total charge of the fully charged battery in order to keep the system operable. "The electrical current that a typical telemetry transaction draws can be measured in milliamps," he says. "As a result, a panel not much larger than a dinner table placemat keeps a unit operational. When you add maintenance-free operation to the picture, you have a system that more than justifies its cost."

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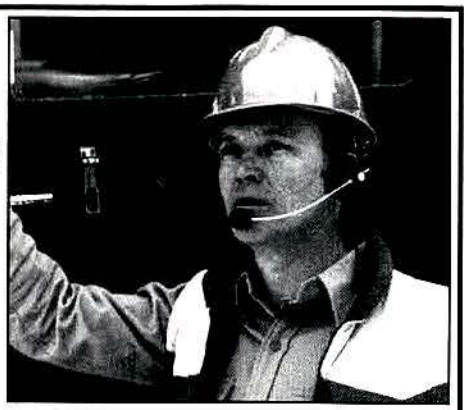

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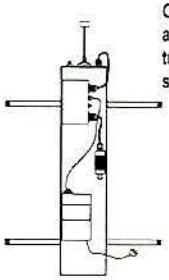

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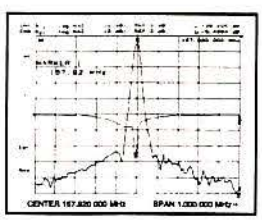

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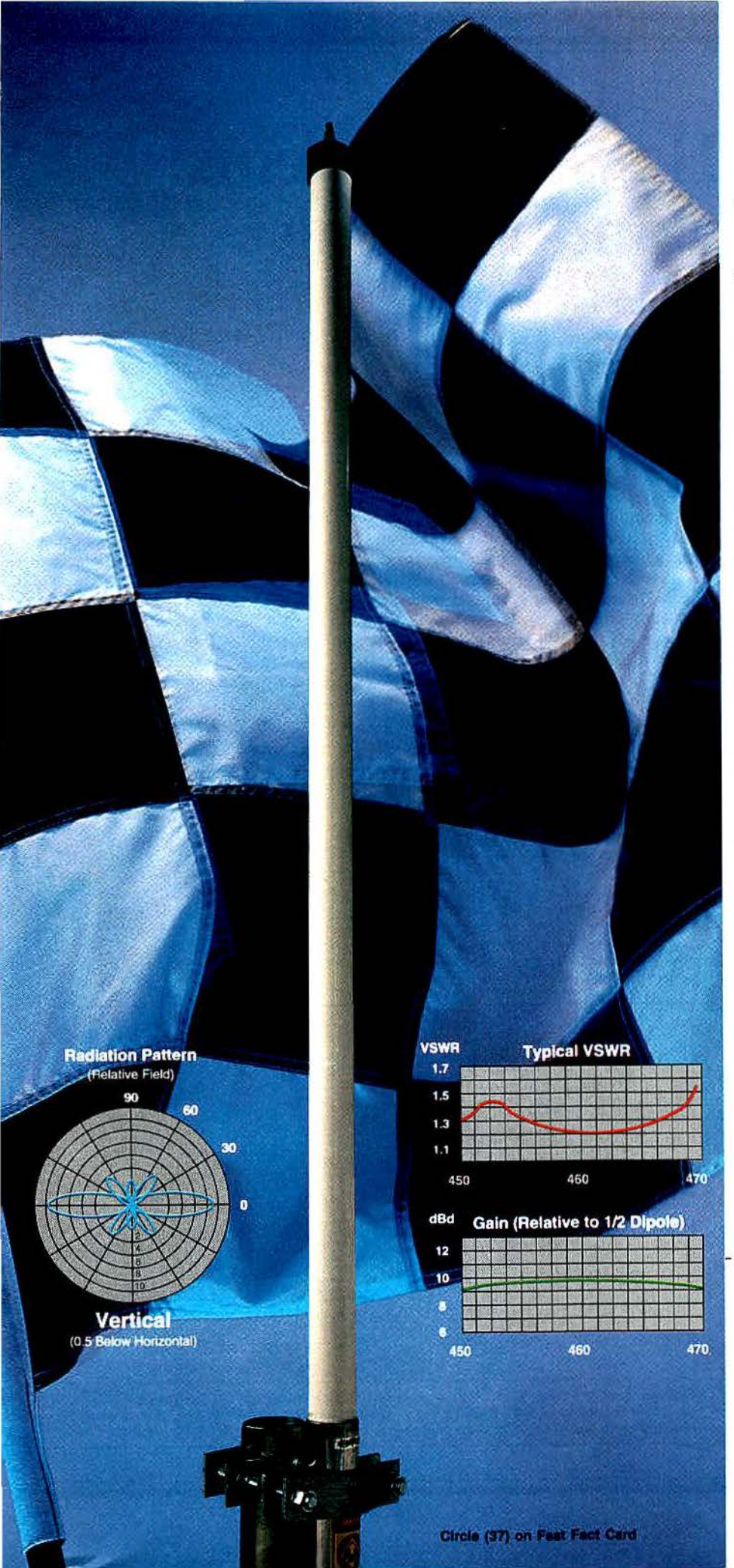

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220MHz SMR systems: Up and running

Incom Communications Company (ICC) is building statewide and regional 220MHz SMR networks leading to nationwide coverage. Dealers, vendors and ICC employees are helping with construction.

By Jack Daniel

The implementation of the newly established 220MHz–222MHz narrowband specialized mobile radio (SMR) systems has started off with a bang. The combination of experienced trunking system operators with the availability of production radio equipment is resulting in a rapid construction of wide-area trunking systems with nationwide networking potential.

Incom Communications Company (ICC), based in Anaheim, CA, is well into an aggressive and advanced program to construct and operate 220MHz narrowband trunking systems nationwide. Starting with a state-wide system in California, ICC will add area-wide systems in several other large markets throughout the United States. Additional systems are already scheduled for construction in Nevada; Texas; Washington, DC; Baltimore; New York City; and Chicago.

The initial phase of the ICC system provides radio coverage throughout the Los Angeles, San Diego and San Francisco metropolitan areas, with most of the network sites already installed and operational. Any additional sites required to provide seamless radio coverage between

Daniel is the owner of the Jack Daniel Company, Cucamonga, CA. He is a member of *MRT's* editorial advisory board and a Fellow in the Radio Club of America.

How SEA 220MHz narrowband radios work

The outward appearance of an SEA 220MHz narrowband radio is similar to many modern FM radio models, but they are dramatically different in their features and technical workings.

Incidentally, these 220MHz radios already comply with the most stringent technical requirements of the FCC's proposed "refarming" (Part 88) rules issued last year. The narrowband approach described here is already available as a means of compliance with the upcoming rules for "very narrowband" (VNB) radio systems using 6.25MHz or less channel spacings.

The 220MHz narrowband radios use advanced RF and audio circuit designs developed specifically for this application, as well as built-in self-diagnostics. Special techniques, such as digital audio processing and high-frequency stability maintenance, are required because of the 5kHz channel-to-channel spacings and narrow channel bandwidths required by the FCC.

Audio frequency tracking between radios, an important factor in all single-sideband communications, is accomplished by the use of a pilot tone. The pilot tone is generated by the transmitting radio, and the receiving radio adjusts its frequency conversion to maintain minimum output audio frequency shifting.

Additionally, the tones provide an audio amplitude reference that is used to eliminate the effects of varying RF signal levels that would otherwise be inherent in single-sideband signal reception.

Audio companding is also used to further improve the signal-to-noise ratio in the received audio output.

Digital signal processing (DSP) is used to implement and to recover the audio, pilot tone and digital data signal protocols. The audio modulation band is digitized, and then split, with the higher-frequency band shifted upward to allow the trunking data to be inserted in the audio band. (See Figure 1 below.) This method sometimes is called *transparent tone-in-band* (TTIB). It improves adjacent channel (*only 5,000Hz away*) isolation.

The digital data signaling is used for either conventional operation (similar to digital squelch) or trunking signaling, according to which mode is being used at the time.

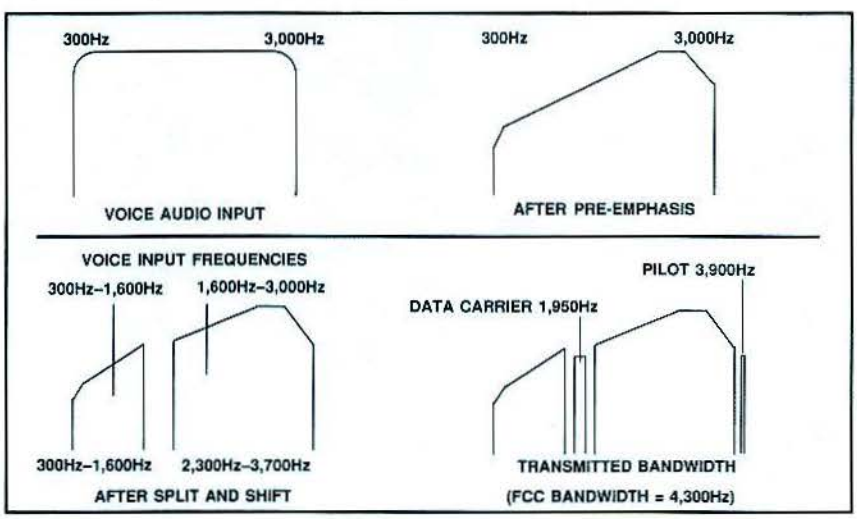

Figure 1. First, the audio voice input is pre-emphasized to shape the frequency response. Then, the audio baseband is split, with the higher-frequency band shifted upward. A data carrier is inserted in the gap at 1,950Hz, and a pilot tone is inserted at 3,900Hz, above the audio baseband.

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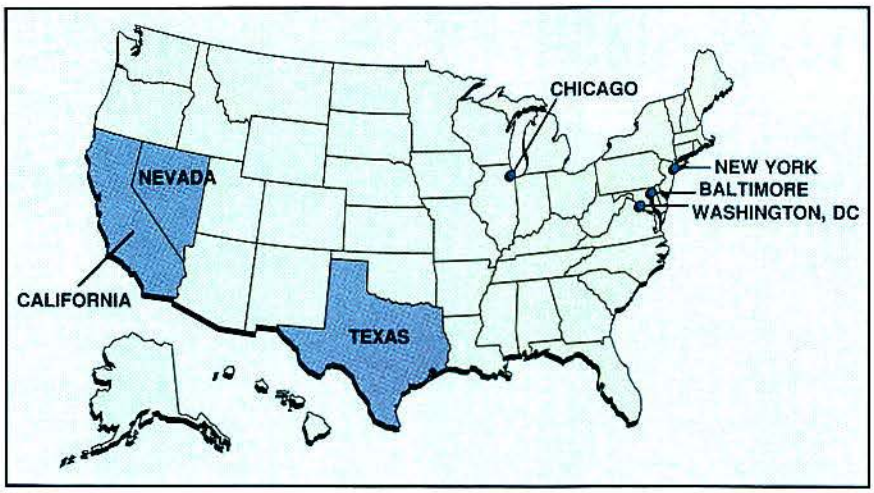

ICC network coverage is initially planned to begin in several key states with eventual expansion into nationwide coverage.

these areas will be installed shortly after the installation of other metropolitan systems nationwide—or sooner, depending upon customer demand and availability.

As of April, ICC had completed construction of more than 100 channels at sites in California. More than 200 channels of additional equipment were already on order and scheduled for installation in other areas during the next few months.

Using channels licensed to ICC and to others, ICC is consolidating individual five-channel trunked licenses into a multichannel trunked radio system that will offer wide-area networking with telephone interconnect, mobile data and other capabilities.

Ron Domres, manager and partner in ICC, says that ICC is continuing to add other licensees to its expanding network. Domres has extensive past experience operating and owning wide-area SMR systems in the 800MHz and 900MHz bands.

The ICC 220MHz SMR network program combines the resources of the licensees and selected vendors, as well as the expertise of ICC employees.

ICC's marketing program is designed to bring loading on the company's 220MHz SMR network to a maximum as soon as possible. Using its own sales agents and the services of cooperative radio dealers, ICC expects to have a strong presence in each market.

To keep the price of the radio equipment and monthly service charges to end-users competitive with comparable 800MHz and 900MHz SMR systems, ICC has selected appropriate radio sites, local dealers, service companies and radio equipment. Additional dealers and channels will be added in each market as necessary.

ICC, as with many others, initially took a conservative view of 220MHz narrowband radio equipment. Extensive internal engineering reviews were made, and "real-life" field tests were performed. The company's managers concluded that

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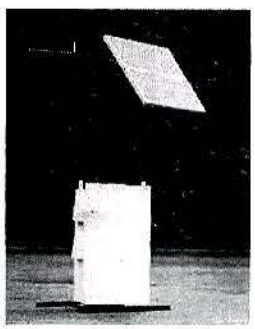

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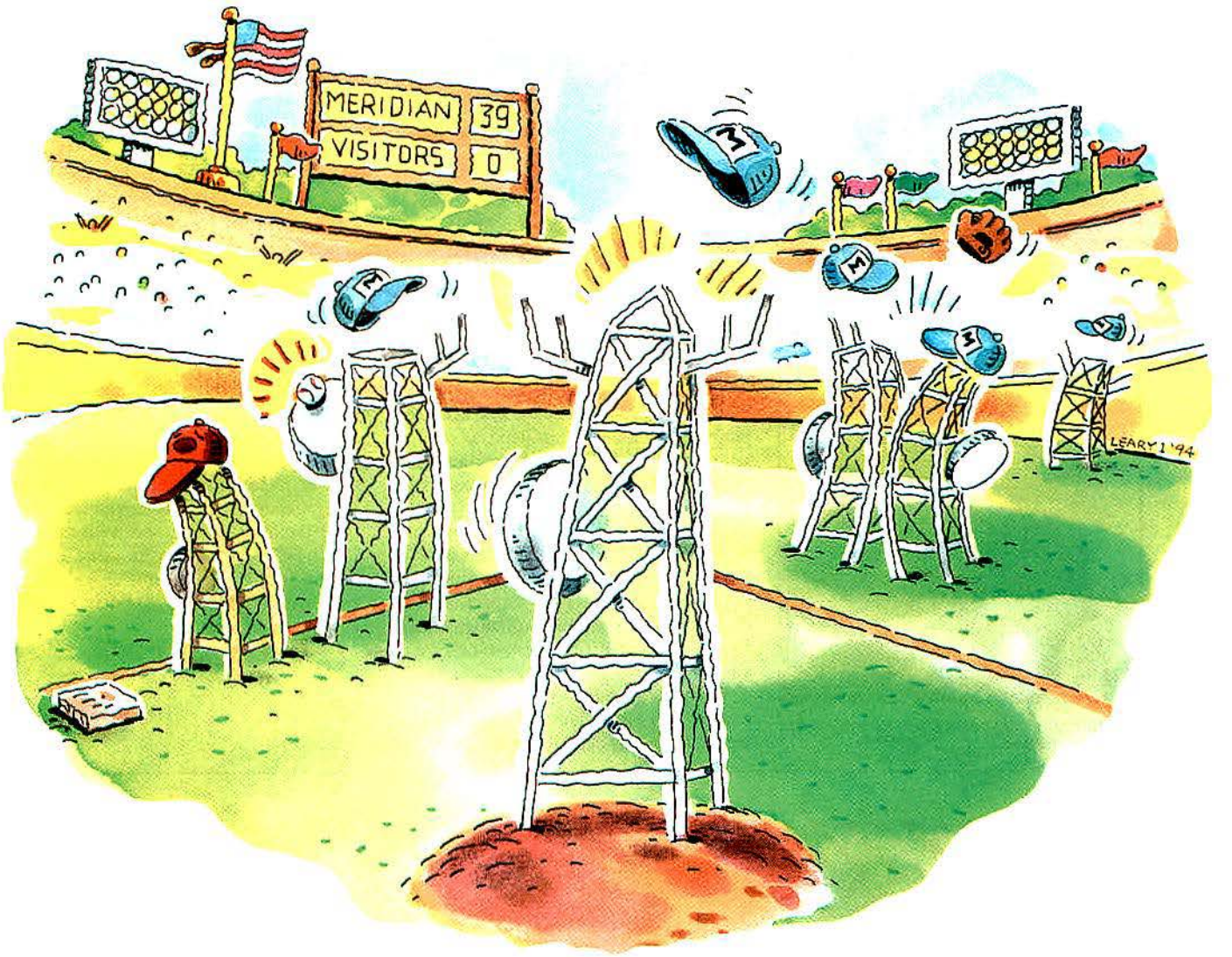

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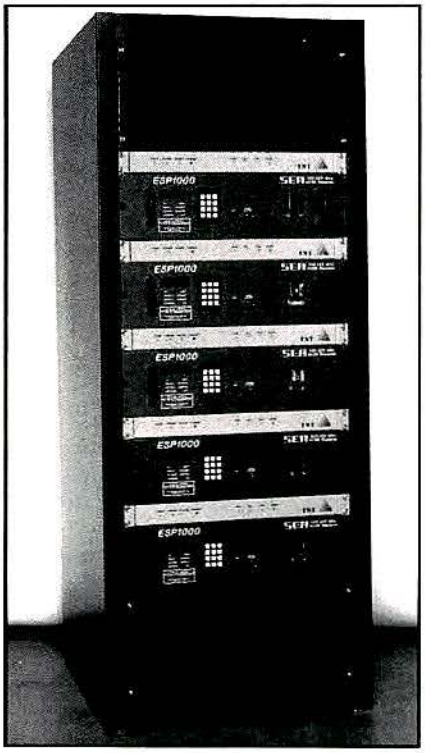

A typical SEA five-channel trunked system fits in a single cabinet.

the new 220MHz radio products work as well as—and in some cases, better than—comparable FM radios. The ICC program required a radio product that was not in the design phase but in actual production to meet their time schedules. The radio manufacturer's ability to provide timely future deliveries, to maintain high quality and to support advanced operations at competitive prices were equally important in ICC's selection of SEA equipment. SEA, based in Mountlake Terrace, WA, is a 220MHz radio equipment manufacturer.

Trident Micro Systems, Fountain Valley, CA, was selected to provide the system controller. SEA repeaters are compatible to Trident controllers, as well as with other controllers that use the same, popular SMR trunking protocol commonly used with 800MHz and 900MHz SMR systems. Wide-area network features will be implemented as the use of the ICC system requires them. Automatic roaming, telephone interconnect, mobile data, messaging (mobile e-mail), vehicle location determination and other advanced features are planned.

Raycom, a radio system engineering company in Paramount, CA, has been selected as the system integrator. Raycom will pretest each system and oversee the installation and initialization of ICC's 220MHz SMR network.

"The systems we are building are not revolutionary," Domres said. "They are real and achievable state-of-the-art systems based on the latest equipment designs and a wealth of experience in building successful and profitable SMR systems. By using the strengths of our business partners and suppliers, we are implementing systems while others are simply talking about it."

Domres said the selected architecture allows ICC to respond to new developments and customer requirements rapidly and economically efficiently.

"We intend to make the investment that may be required to meet our goals, including purchasing the site equipment or the sites themselves. We see no reason that ICC won't be as successful using 220MHz narrowband SMR systems as anyone has been with 800MHz or 900MHz FM SMR systems," he said.

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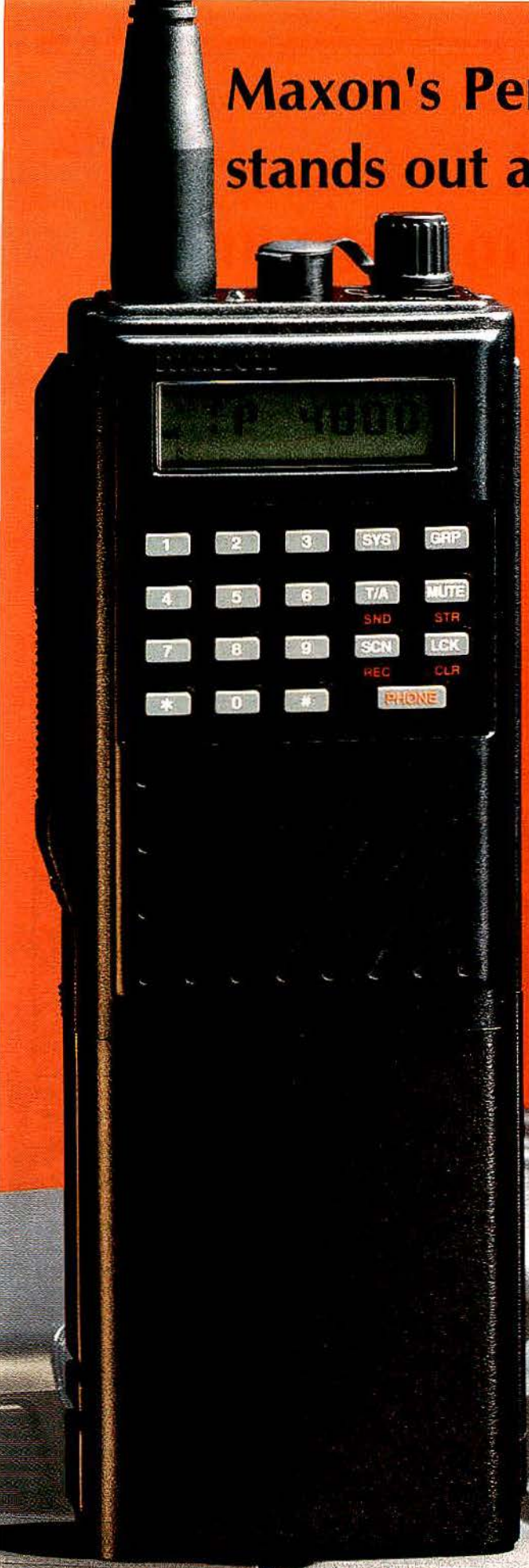

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Photo enlarged to show detail.

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Tile analysis plots coverage for utility radio networks

Tile analysis using desktop computer equipment allows engineers to evaluate more information with greater speed — a development that makes system design more reliable and cost-effective.

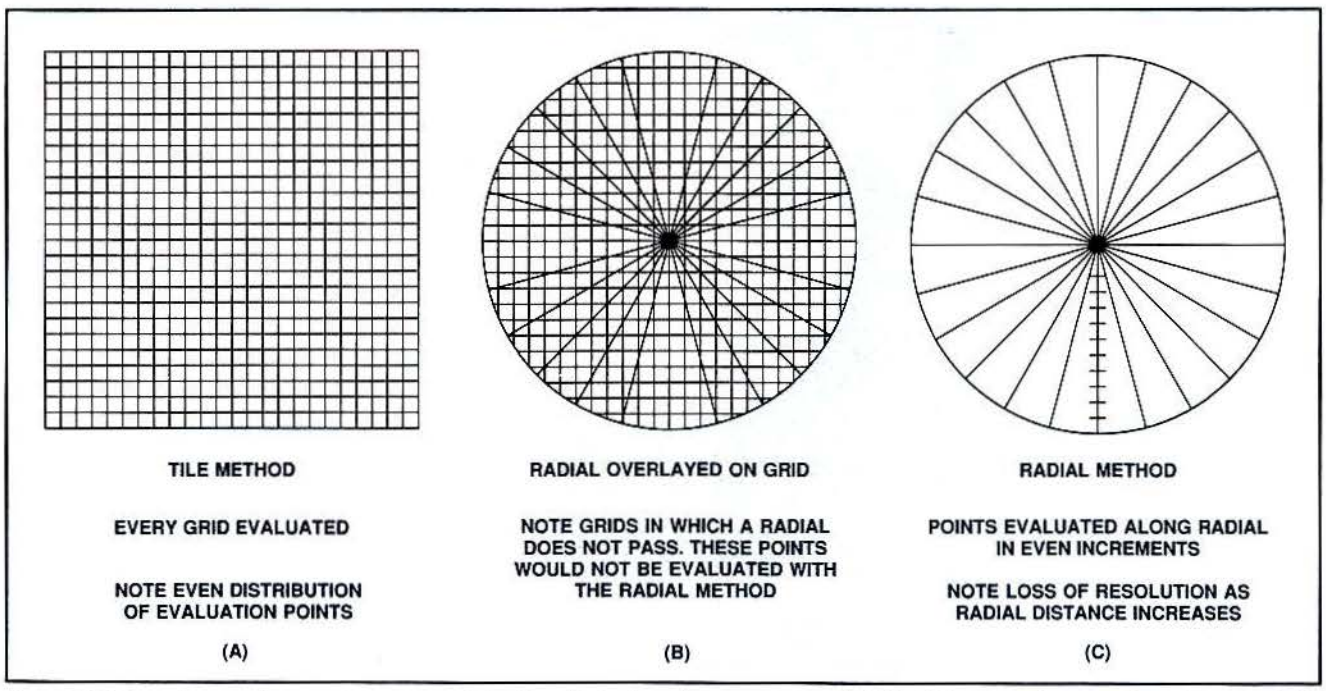

Figure 1. (A) Several new software programs use a technology that subdivides coverage areas into small, distinct sectors called *tiles*. (B) For mobile coverage prediction, for example, radials are constructed within the program once individual tile data values have been determined. (C) Previous to tile analysis, coverage prediction for two-way radio was accomplished by means of a *radial* method.

By Bernie Olson

Two-way radio networks have become indispensable elements of the utility industry. From maintenance crews and service employees in the field to supervisors and on-site technicians, utility specialists have come to rely on the radios clipped to their belts or mounted in their vehicles.

Although radio hardware is familiar to everyone, many people do not realize that, with today's digital capabilities, the communications system's more intangible *software* plays an integral role in building a reliable communications network as well.

Prior to the installation of any local or wide-area communications system, computer programs with cutting-edge technologies such as compact-disk read-only memory (CD-ROM), three-dimensional spreadsheets and screen window user-interfaces are used to analyze an operational area for possible interference sources and transmission variance factors. This helps determine how communications hardware must be tailored to perform best for that system.

When engineers design a two-way radio system, they must carefully craft a solution that satisfies the user's requirements by determining available resources and cost-effective implementation. Variables that engineers must consider typically include the availability of frequencies and the use of sites already owned by the customer, as well as the cost of system maintenance. Whether a new communications system is being installed, or an old one is being modified, communications experts ask some key questions:

- ☐ Where does it need to communicate?
- ☐ How many sites are necessary?
- ☐ How many frequencies are necessary?
- ☐ Can existing frequencies be reused?

Olson is manager, resource development engineering, National Engineering Services, Motorola Land Mobile Product Sector, Schaumburg, IL. Motorola offers a tile coverage analysis system under the name Mozaik.

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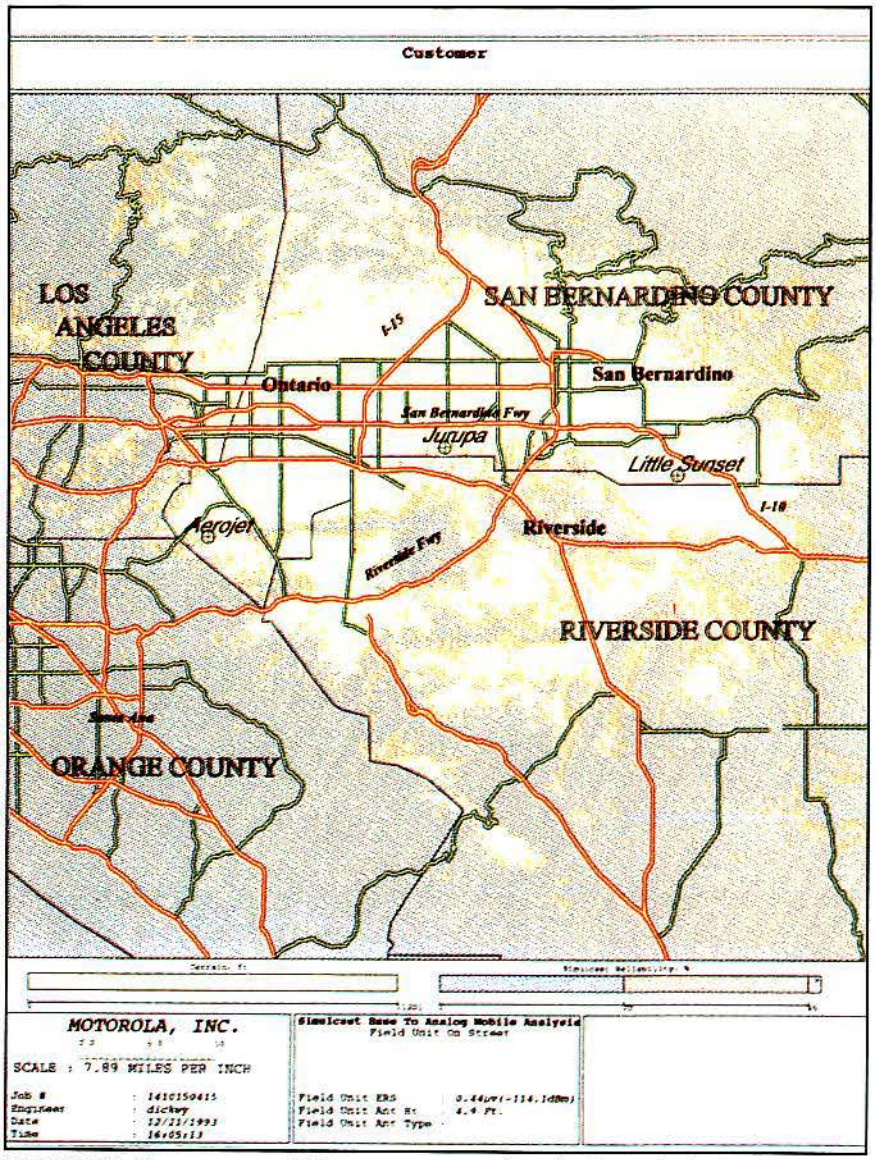

Figure 2. With tile coverage prediction, on-screen map data showing roads, bodies of water and political boundaries allow the user to determine the location of problem areas relative to these references.

Previous methods used to answer these questions were greatly outpaced by communications technology. Whereas radios, pagers and cellular phones have become smaller, more powerful and more versatile, coverage prediction methodology remained practically unchanged for more than 20 years.

Fortunately, a remarkable improvement has been made in coverage analysis—an improvement that brings prediction capability up to speed with today's most advanced networks.

Improved coverage predictions

Several new software programs use a technology that subdivides coverage areas into small, distinct sectors called *tiles*. (See Figure 1A on page 46.) These tiles are subject to an extensive battery of evaluative procedures that provide key information to designing an effective two-way radio network.[1] Tile coverage analysis can be used with radio systems operating in the 25MHz–2GHz range for mobile coverage and at frequencies as high as 23GHz for fixed point-to-point communication.

Although the prediction analysis method for each system will change, the basic tile method remains constant. For mobile coverage prediction, for example, radials are constructed within the program once individual tile data value has been determined. (See Figure 1B.) This allows coverage values to be predicted for specific tiles. The tile method's grid-pattern analysis provides more than 300 predictions per square-mile, nearly 100 times better than radials at typical reuse distances from a site.[2]

Prior to this innovation, coverage prediction for two-way radio was accomplished with a *radial* method. (See Figure 1C.) Coverage points within a proposed coverage area were analyzed at uniform intervals radiating from the radio site at some fixed angular increment. This meant that the terrain variations for a particular segment and the subsequent effects they would have on predicted system coverage were based on as few as four points per mile along the radial. Even more area was missed the farther from the site the evaluation was made.

Fast, easy analysis

Until recently, the coverage prediction process required that maps with comprehensive terrain data be painstakingly converted to data a computer can use. After loading this information, the computer would apply programs that calculated the effects of terrain variations and equipment configurations on the predicted receive signal levels. Even when the terrain information became retrievable via computer, the process was still laborious and repetitive. Mainframe units had to generate predictions and then output the results for each specified configuration. Configuration adjustments could be achieved only by re-running the entire application.

Now, terrain data are available on CD-ROM, and solutions can be quickly viewed to determine the results of configuration changes. In addition to terrain data, coverage performance also can be evaluated based on the land use in each tile. Land use has a direct effect on the losses assigned to a given tile. A land-use database can categorize a tile as urban, suburban, open area, forest, etc. These categories are then translated to loss values appropriate to the chosen frequency band and used to predict signal levels of that particular tile.

Previously, coverage predictions had to use a general environmental value, and the entire program had to be re-run for each value. Users were forced to inspect the results and to integrate them based only on local knowledge of the land use—an ex-

1. There is an extensive amount of data that can be evaluated in each tile. The informational layers include: distance and azimuth to the site(s), terrain elevation, land usage, free-space loss, prediction model basic loss, predicted mean signal level, probability of achieving mean signal level, margin vs. target reliability, shadow loss, C/I for multisite, probability of achieving multisite target C/I, probability of achieving multisite target (C/I 1 N), simulcast performance delay characteristics, and probability of achieving multisite target simulcast delay/signal level characteristics.

2. Based on a potential improvement from four points per mile at 57 miles compared to 378 calculations per square mile at 37° north latitude, average for the continental United States.

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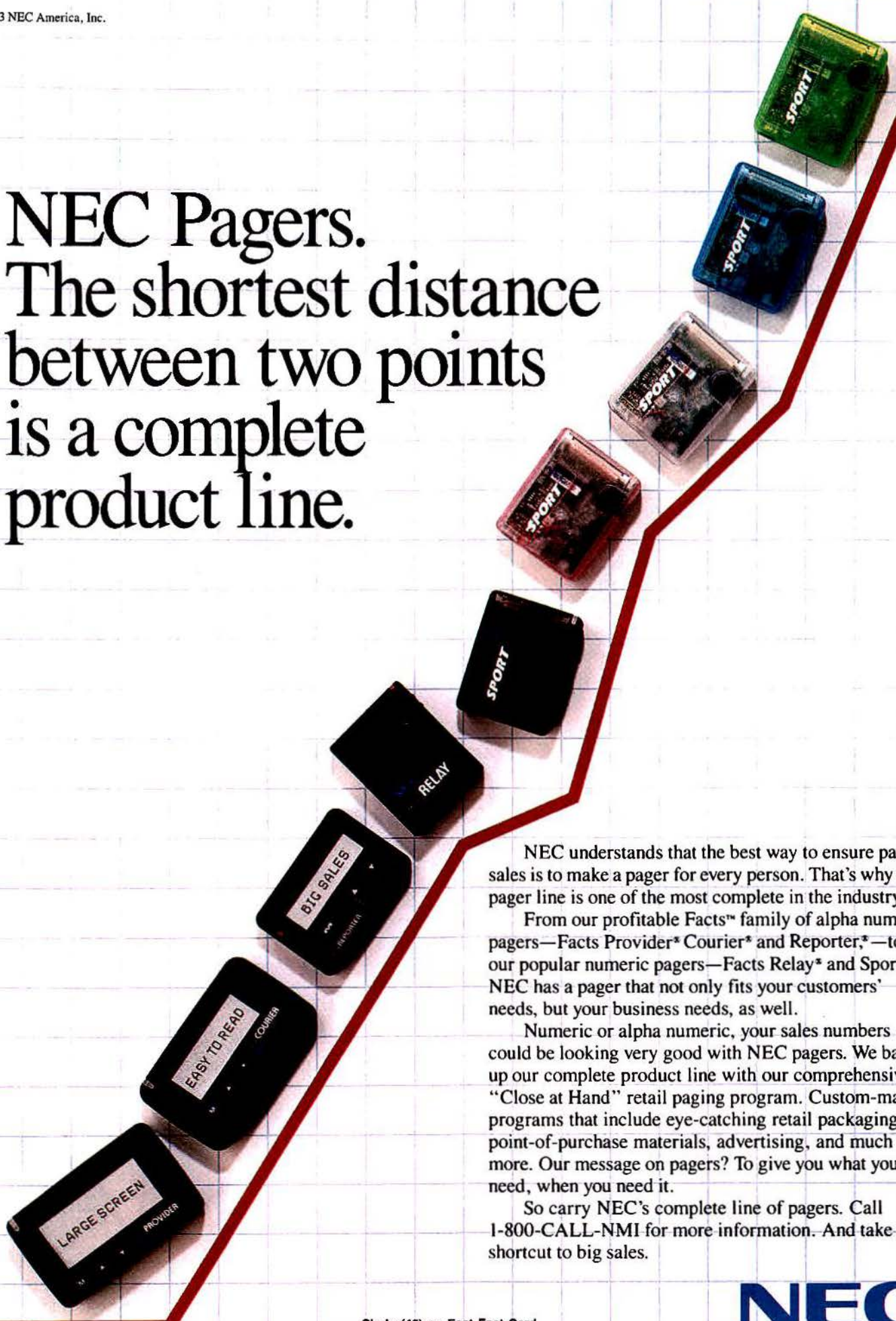

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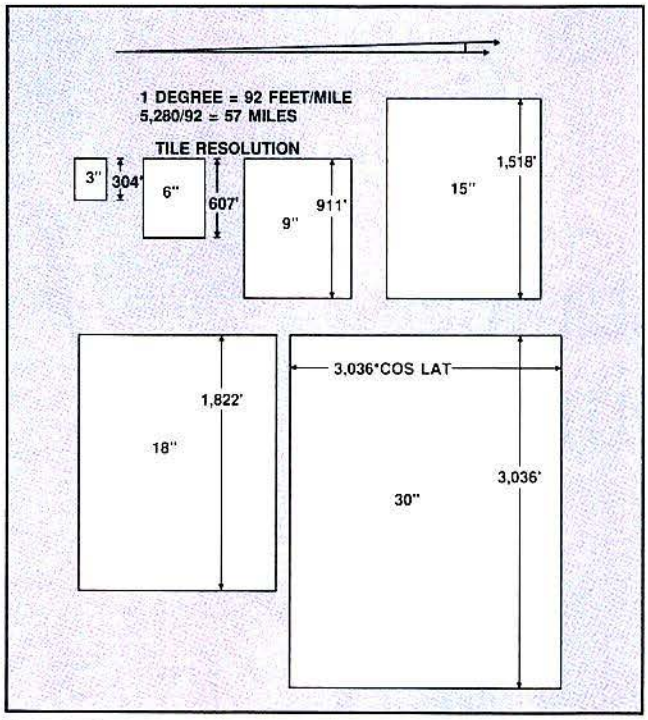

Figure 3. The coarsest tile resolution is approximately 3,040 feet by 3,040 (cosine latitude) feet. The finest resolution is approximately 304 feet by 304 (cosine latitude) feet.

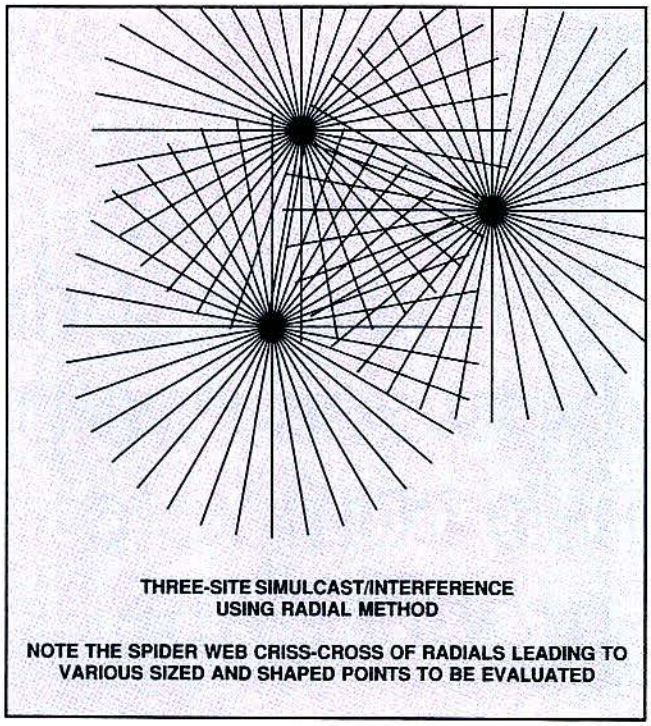

Figure 4. With radials, it is difficult to find enough multisite radial intersections for high-resolution solutions. Even with radials at every degree, when the radial is longer than 57 miles, the separation is too great for predicting multisite network coverage.

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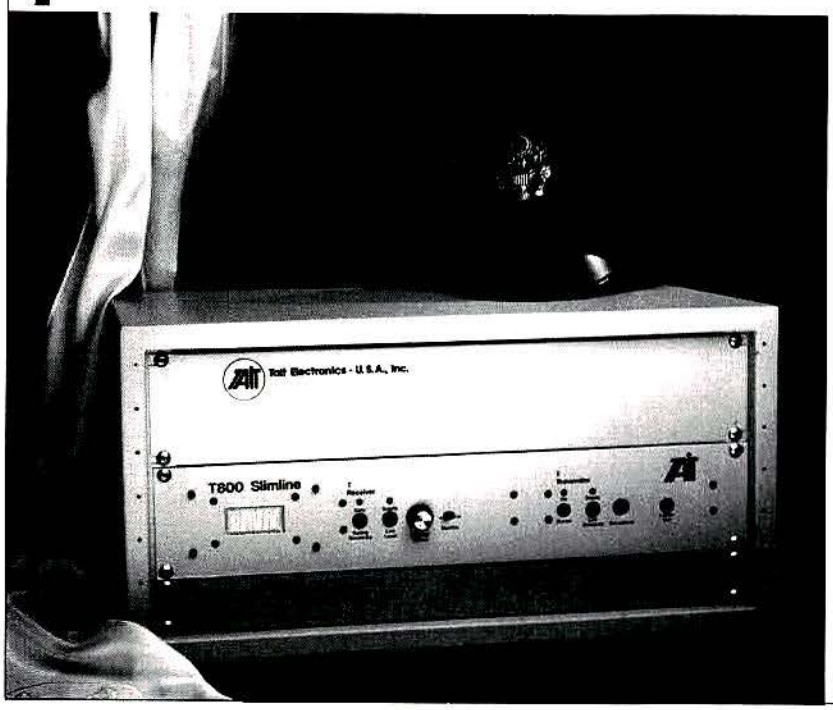

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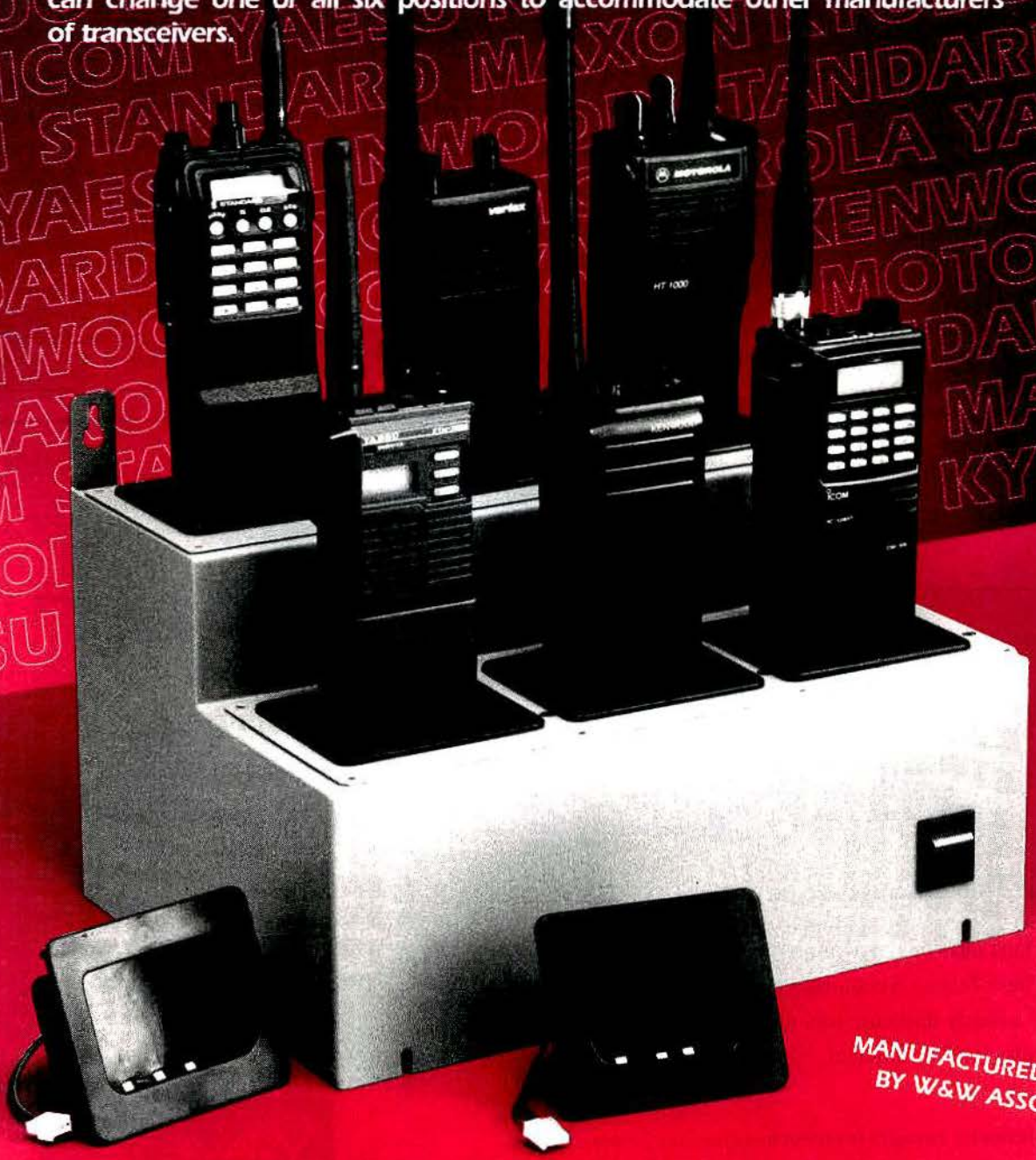

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results and to integrate them based only on local knowledge of the land use—an extremely unreliable method.

With tile coverage prediction, individual environmental effects on the system can be calculated for each tile, rather than applying a global effect across the entire evaluation area. On-screen map data showing roads, bodies of water and political boundaries allow the user to determine the location of problem areas relative to these references. (See Figure 2 on page 48.) CD-ROM becomes instrumental in these calculations because it is remarkably easier to distribute and store the massive amounts of data available for use by a tile system. In addition to being practically indestructible, a single CD-ROM can store 650 megabytes of data.

Enhanced resolution

Engineers can analyze tiles of various resolution to select the amount of precision they require for a particular type of system or design phase. The coarsest resolution is approximately 3,040 feet by 3,040 (cosine latitude) feet. The finest resolution is approximately 304 feet by 304 (cosine latitude) feet. (See Figure 3 on page 50.)

When radials are constructed, it is difficult to find sufficient multisite radial intersections to provide high-resolution solutions. (See Figure 4 on page 50.) There is no way to guarantee that an intersection will occur at any area that demands such scrutiny. Even with radials at every degree, the separation is too great when the radial is longer than 57 miles. Accuracy at this extreme, for radial coverage analysis, is simply too coarse for predicting multisite network coverage.

Digital technology has changed the criteria for channel performance from average signal level to more performance-based characteristics.

Channel performance predictions

Digital technology has changed the criteria for channel performance from average signal level to more performance-based characteristics. These include users' opinions of audio quality and the probability of achieving a required performance bit error rate (for specific modulations and applications), as well as ratios between desired signals and detracting sources, such as noise and interfering signals.

Ultimately, performance characteristics will vary with modulation type and user mobility. Normal analog FM voice transmission requires a margin of about 10dB over the 20dB quieting performance. This can be converted to a 17dB C/N to deliver a circuit merit 3 mean option score in a moving receiver. Different criteria for channel performance can be converted into an appropriate C/N or C/(I + N).

The design of both digital and analog systems is possible because various grades of performance are based on the specific modulation used, and the coding scheme's "robustness." The primary difference between digital and analog designs is that analog degrades slowly until it reaches a threshold grade of performance, whereas digital operates at a nearly constant grade of performance, then rapidly degrades with reduced signal levels. The engineer must

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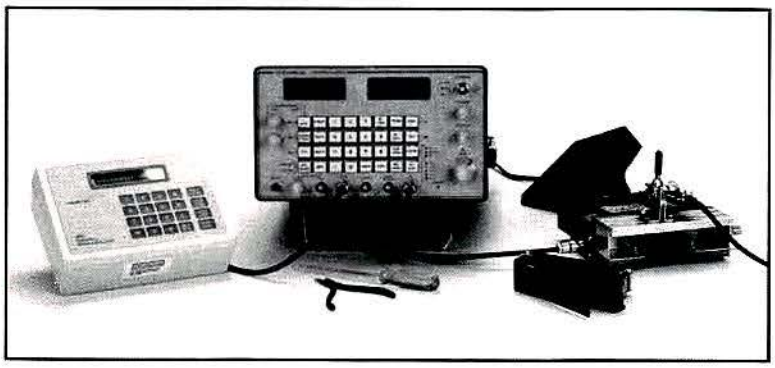

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Most Trunking Radio Users Are Locked Into One Format

There are two primary 800MHz trunking formats, LTR and Privacy Plus. And they are not compatible. That means if you purchase radios specifically designed for one format, they are worthless if you want to use the other trunking format.

The good news is in most areas, both formats are available. The bad news is that most trunking system users can only operate in one format.

They are "Captive Customers" locked into one system (and probably that operator) for as long as they own their radios. And there is no option to change or improve their coverage and service.

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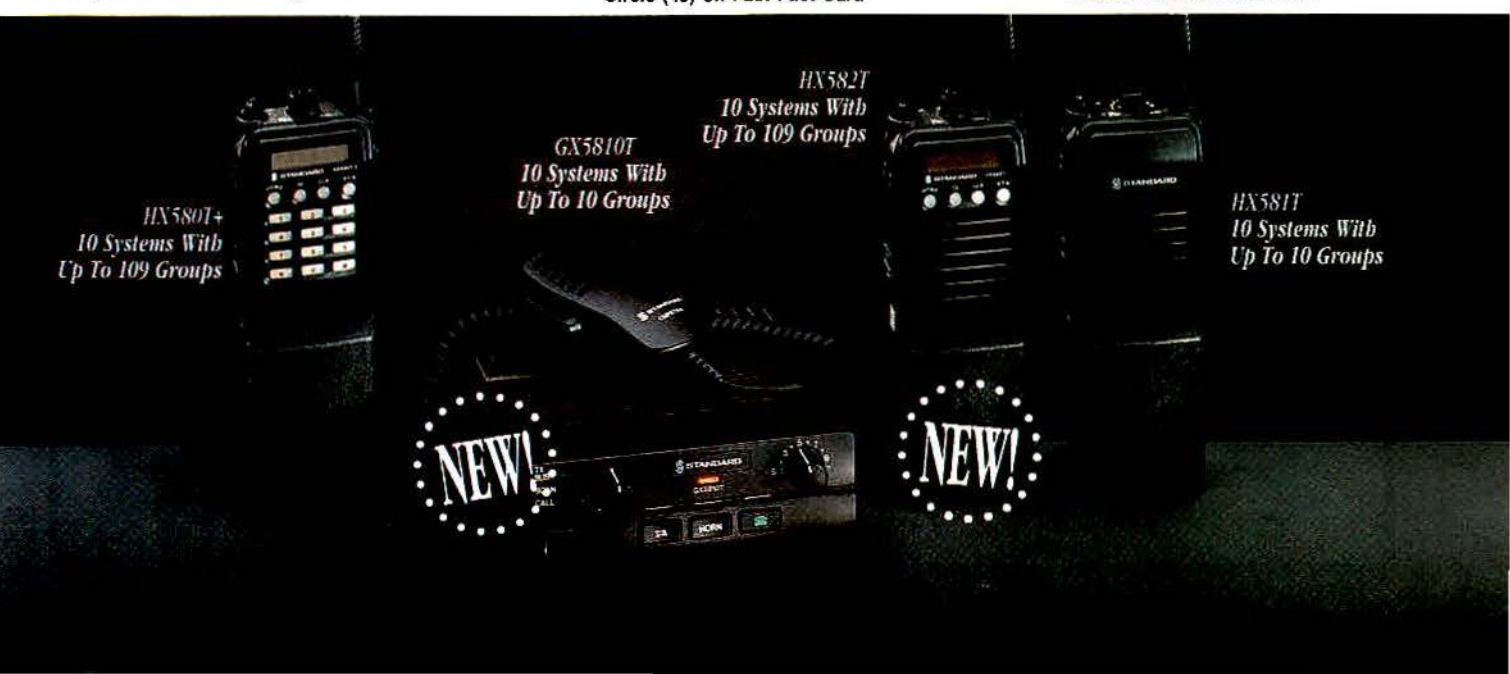

be aware of these differing degradations to properly incorporate the requirements into the design.

By using tiles, sophisticated "simulations" can be performed in individual tiles. (See Figure 5 on page 56.) A tile system is, therefore, the only accurate way to predict the probability of network transmission quality over extended service areas, including the effects of hardware configurations, terrain, micro-land use environment and frequency reuse.

Data presentation and analysis

Data values are available from stored data, similar to a three-dimensional spreadsheet; the service area is represented as a rectangle, and the calculated or simulated values and data are vertical information layers. Individual and multiple layers can be displayed on computer screens or as printouts. Engineers can easily examine the effect that changes in propagation values and profile-dependent characteristics will have on the system. Adjustments to transmitter power, antenna pattern or tower height, for example, will cause only the appropriate recalculation, not necessarily a complete recalculation.

The informational layers generated by the tile system's calculations can be color-coded on-screen for clarity and quickly displayed for further analysis or amendment. High-resolution video and a large color palette can show myriad permutations of system coverage.

The computations of a tile system are so detailed that coverage prediction can be analyzed down to an individual tile. These systems can display informational layers for any selected tile and construct profiles of menu-selected informational layers from the tile back to the site(s). This allows engineers to determine possible coverage problems, rapidly test solutions and view their results. Changing power output or antenna gain, for example, merely changes the equipment margins. A more complex modification, such as tower height, requires a more extensive recalculation process, but overall system assessments can be quickly revised without having to remodel the entire scenario.

With multiple sites, relationships can be viewed so that performance interactions are optimized. This gives installers the distinct advantage of being able to engineer the interaction between sites using the same frequency and engineer hardware selection—a condition that formerly did not occur until after the equipment was fielded. This dramatically quickens system design and the installation process for a communications system.

Engineers who are given the ability to model single-site performance, co-channel sites and simulcast configurations can rapidly determine the effect of varied tower heights, antenna patterns and transmitter power levels. Without tile-based coverage prediction, system problems would have to be resolved during actual installation—a time-consuming and costly alternative.

User interface and coverage process

Employing today's popular icons, objects and screen windows, the program makes coverage prediction as simple as the *drag and drop* method. Icons representing the various elements of a system are manipulated to create a scenario to evaluate. This interaction is very similar to the process an engineer would use to develop a system diagram.

Certain objects can contain other objects. A site object, for example, would contain objects representing a transmitter

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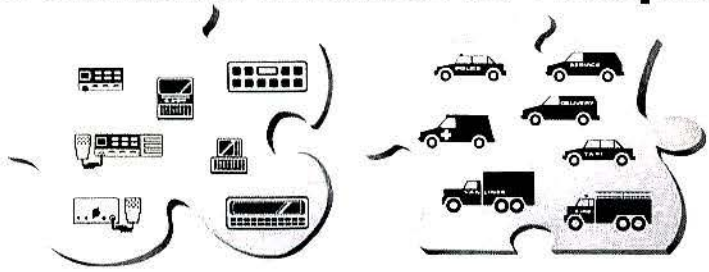

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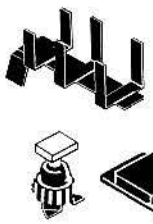

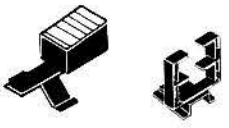

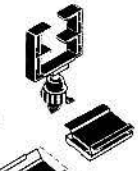

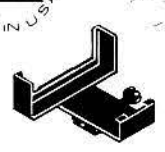

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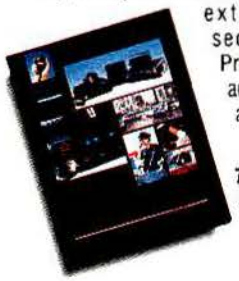

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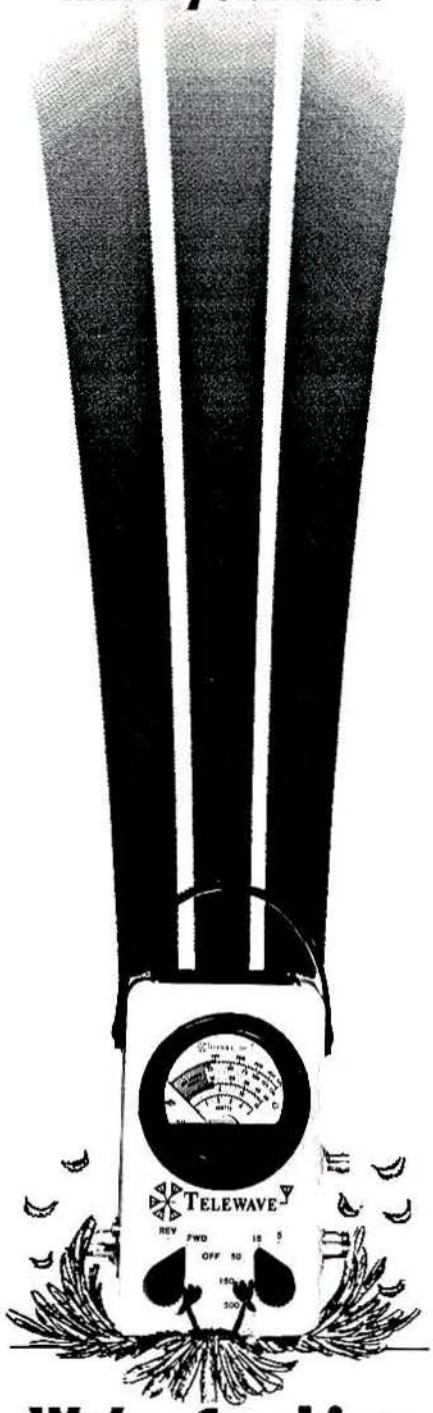

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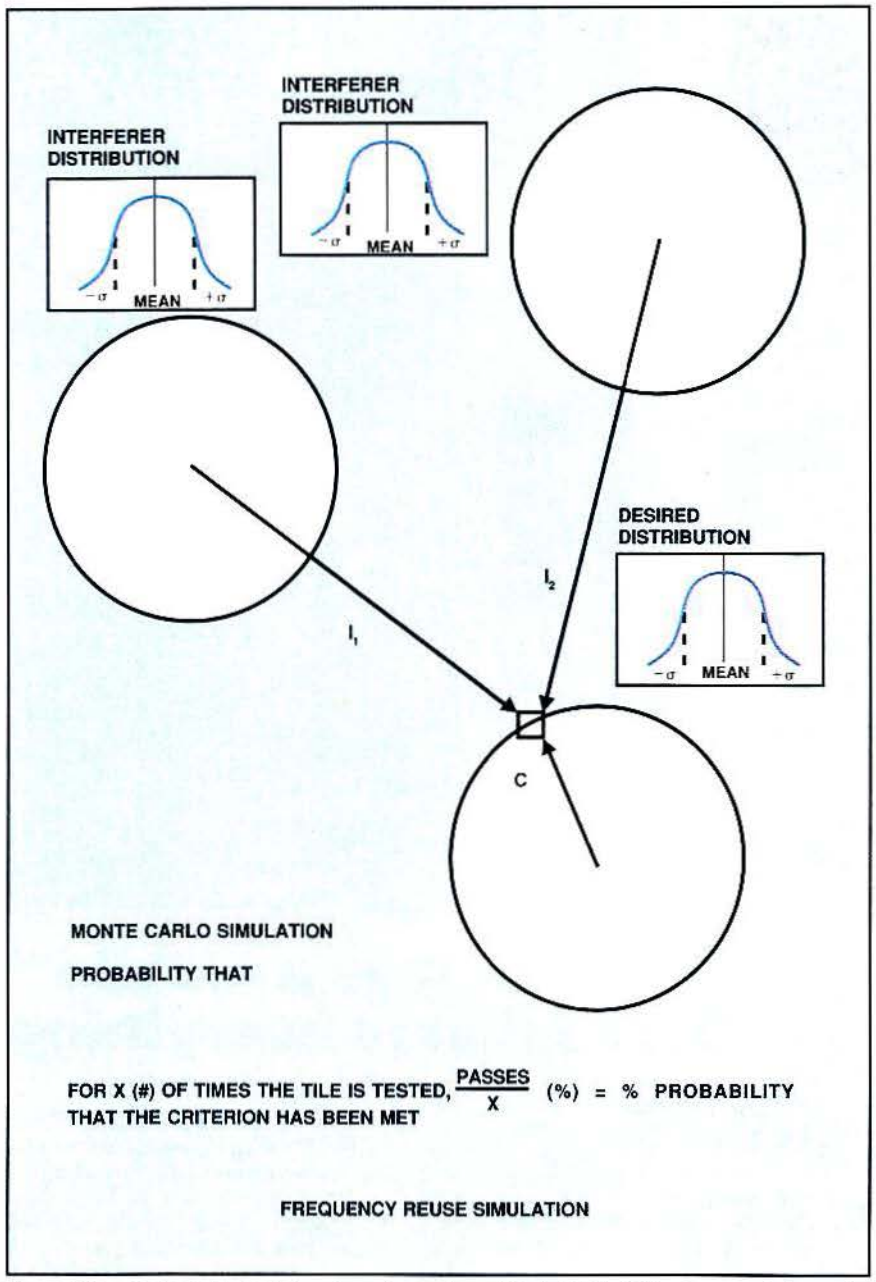


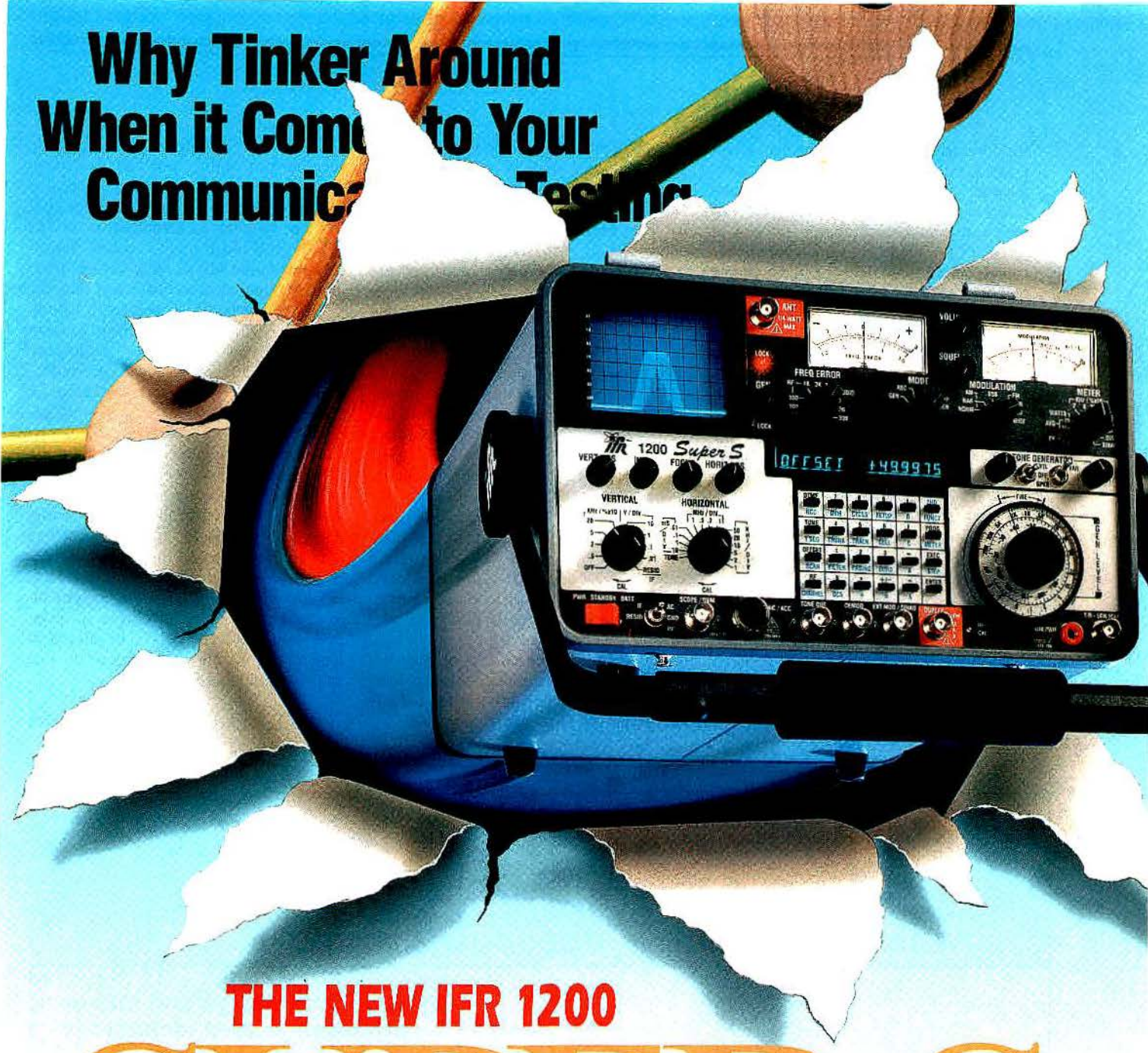
Figure 5. Sophisticated 'simulations' can be performed in individual tiles to accurately predict network transmission quality over extended service areas, including the effects of hardware configurations, terrain, micro-land use environment and frequency reuse.

and receiver configuration. Each object is linked to a notebook that can be opened, and appropriate information can be entered. Thus the site's name and location information would be entered on its notebook page(s). The various network equipment configurations can be selected and then dragged and dropped into the site. As these objects are opened and examined, their characteristics can be entered. Various sites can then be placed into a service area, including objects representing the specific type of user radios, thereby creating a complete scenario that can have its performance modeled.

With the window-icon-object methodology, tedious command-line approaches that require recalling cryptic coded file and program names are eliminated, making coverage analysis dramatically faster and easier. Common configurations can be saved so that only minor updates to the specific data are required for a new prediction.

Co-channel reuse

For exclusive co-channel reuse, the FCC requires that proposed systems be analyzed



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for coverage compliance.[3] A radial system is used, rather than a tile system, to produce an unambiguous result that is much more convenient to administer, but not necessarily more accurate.

The FCC's model uses only three directional radials to determine the antenna height above the average terrain, calculated by averaging the three radials.[4] Each radial is limited to data points located from 2 to 10 miles from the site. This method calculates a radius of coverage for a particular site. The potential reuse site follows an identical process, allowing the FCC to determine the distance to its interference contour. If there is no apparent overlap between the existing coverage contour and the potential interfering contour, the FCC will grant a license.

Tile systems are infinitely more accurate than the FCC's method, which is designed for administrative convenience. They are capable of predicting the probability of providing a desired grade of performance both before and after a co-channel site is simulated, not only in a limited region between the sites, but over the entire potential coverage area of each site. The tile process better represents the user's needs and expectations. It is best used by frequency coordinators representing a class of user and for intra-system reuse.

3. Exclusivity, which is granted in the 800MHz/900MHz band, requires that minimum channel loadings be achieved to qualify. Users not obtaining exclusivity share a channel with other users in the same geographic area.

4. One radial is from the existing site to the new site. The other two are ±15° from that azimuth.

Tile coverage analysis system

As an element of a utility wireless communications and information network, one particular tile system achieves maximum effectiveness and includes IBM's OS/2, 32-bit operating system, which is more powerful than DOS-based operating systems. Usable on PCs rather than RISC-based work stations, the tile system uses four CD-ROMs to provide U.S. terrain data, land use data and cartographic data such as rivers, roads and political boundaries. Specific land use data increases prediction accuracy.

On-screen viewing relative to map data provides iterative problem solving, individual tile characteristic viewing and site or tile profile characteristic viewing.

Simulations in individual tiles provide accurate probability, not calculable any other way. Video resolution is recommended to be SVGA in 256 colors, but VGA in 16 colors is supported, as well as 1024 × 768 and 16 million colors. Selectable resolution allows time-saving, first-draft solutions and accurate final designs.

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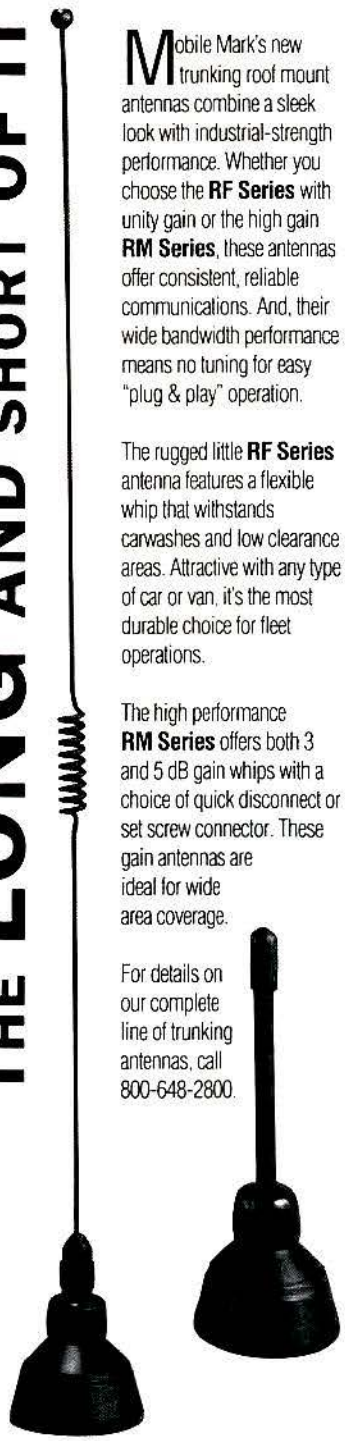

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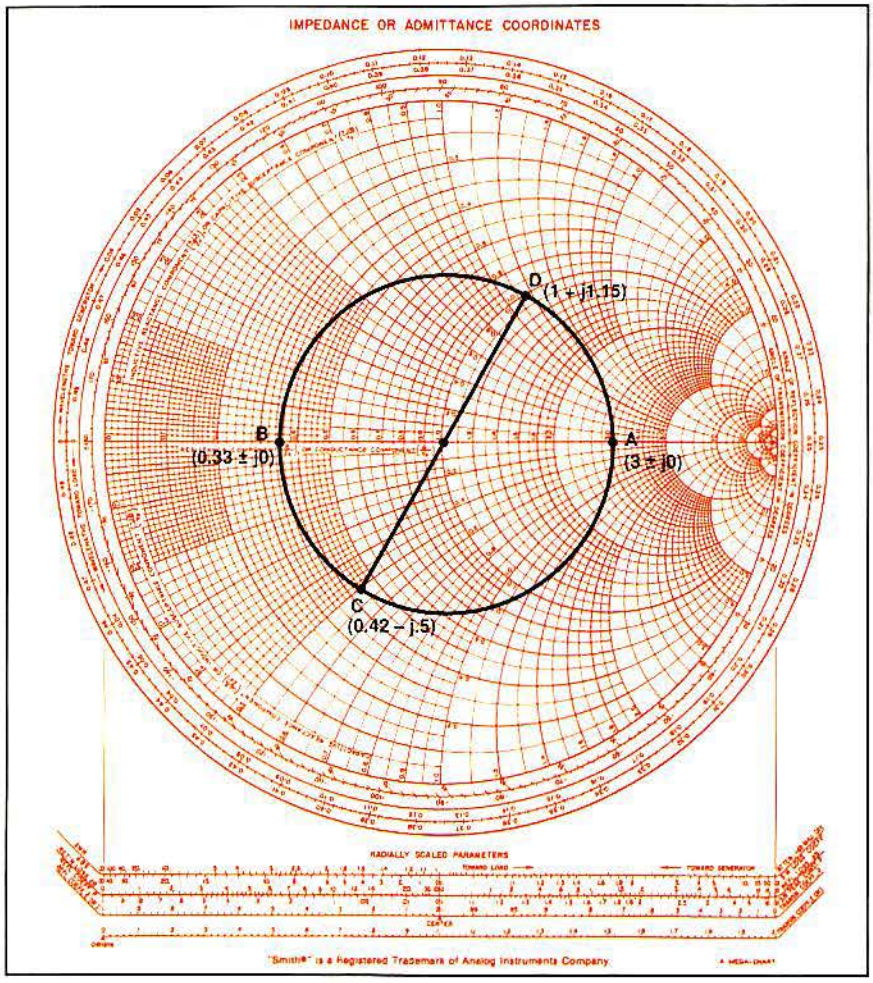

Figure 2: The Smith chart, showing the constant VSWR circle and how impedance/admittance changes through a distance of one-half wavelength. See text for discussion.

(continued from page 8)

located at Point A on the Smith chart in Figure 2 above. Once this point is located, a *constant VSWR* circle is drawn through this reference point using the center of the large circle as the origin.

When a transmission line is terminated in an impedance, Z_L, not equal to the system impedance, Z_0, the line is said to be resonant. The length of a resonant line is critical. The impedance of a resonant line changes over a range of values through every half wavelength ($\lambda/2$). At any two points on a transmission line separated by one-half wavelength (or multiples thereof), the impedance is the same. At any two points on a transmission line separated by one-quarter wavelength (or odd multiples thereof), the impedance is completely transformed. An *open* at a point on a transmission line becomes a *short* one-quarter wavelength away. Capacitive reactance is transformed into inductive reactance a quarter-wavelength away and vice versa.

Refer again to the Smith chart in Figure 2. On a lossless line, the VSWR is the same at all points on the line. The impedance changes through every half-wavelength of line and repeats this cycle of impedance changes on every half-wavelength of line section. On the circle in Figure 2, *one complete revolution represents one-half wavelength of travel*. Moving *clockwise* from the point of reference is *toward the generator*. Moving *counterclockwise* from the point of reference is *toward the load*. One-half revolution represents a change of one-quarter wavelength.

At Point A on the VSWR circle (Figure 2), the normalized impedance is $(3 \pm j0)$ or simply 3. One-quarter wavelength away (Point B), the impedance is transformed to a normalized value of $(0.33 \pm j0)$. At Point C, the normalized impedance is $(0.42 - j0.5)$. One quarter wavelength from Point C (at Point D), the normalized impedance becomes $1/(0.42 - j0.5) = (1 + j1.15)$. Remember, to get the *actual* complex impedance, you must multiply the normalized impedance by the system impedance, 50Ω in this case. So, the impedance at Point C is $50(0.42 - j0.5) =$

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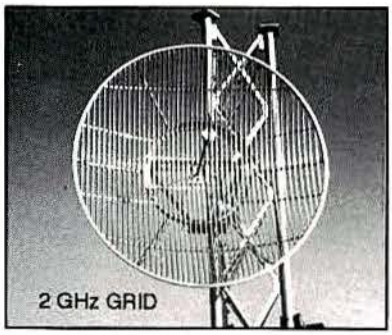

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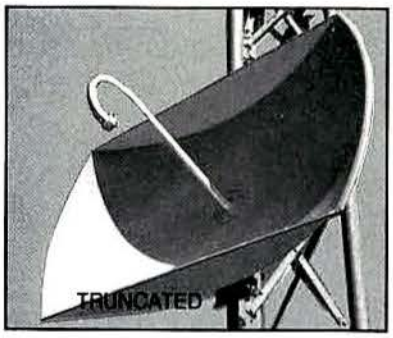

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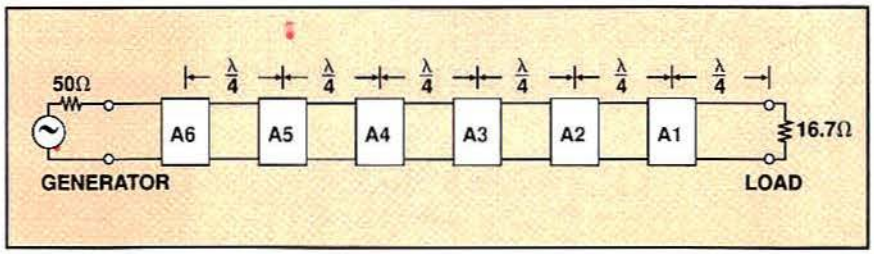

Figure 3: A load impedance of 16.7Ω is connected to a transmission line (Z_0 = 50Ω). The VSWR is 3:1 at the load. Attenuators are placed every quarter-wavelength along the line between the load and the transmitter.

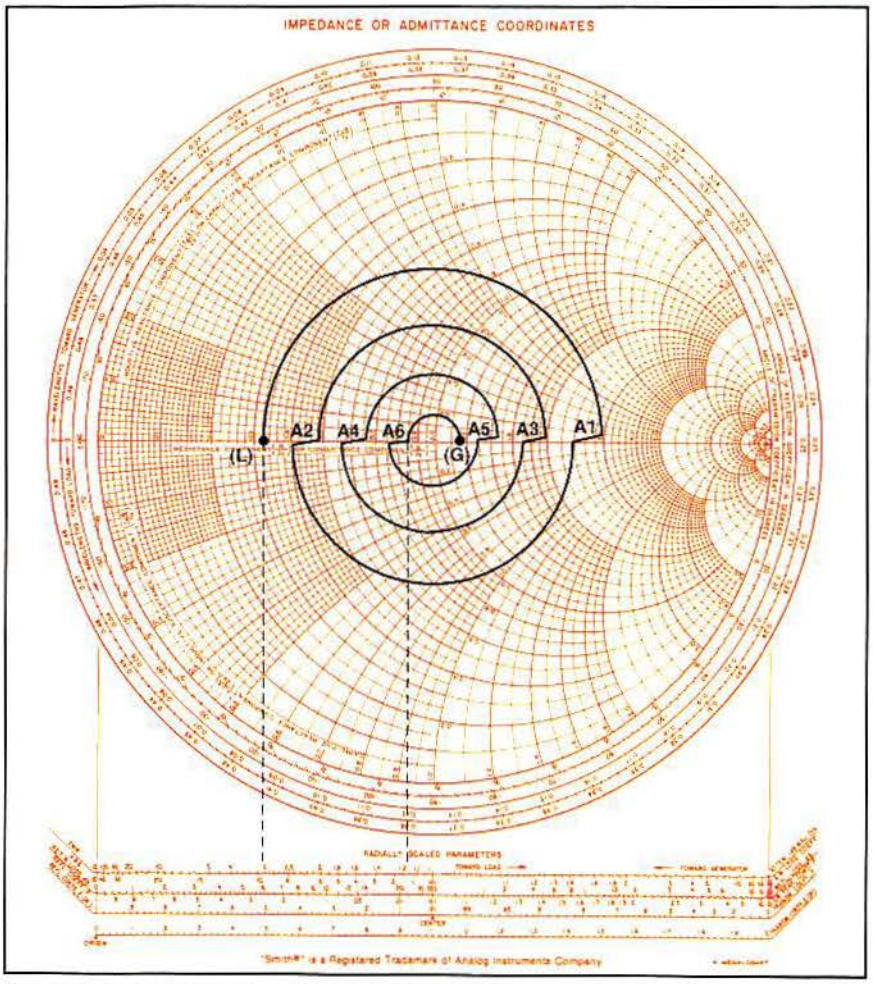

Figure 4: This chart shows the effect of the Figure 3 attenuators placed on the transmission line between the load and transmitter. Notice at each attenuation point that the VSWR circle draws in toward the center. A transmission line with its evenly distributed attenuation would produce a continuous smooth inward spiral instead of the sudden changes depicted by the chart.

$(21 - j25)\Omega$. The impedance at Point D is $50(1 + j1.15) = (50 + j57.5)\Omega$.

An important and useful feature of the Smith chart is that the *equivalent normalized admittance* lies on the circle just opposite the normalized impedance point. For example, in Figure 2, we can convert the *normalized impedance* at Point C $(0.42 - j0.5)$ to the equivalent normalized admittance (Point D) of $(1 + j1.15)$. To convert from admittance to impedance or vice versa, simply draw a line from the point of reference through the origin to the intersection of the circle on the other side (a quarter wavelength away). Just remember that the equivalent normalized values of admittance and impedance lie on the VSWR circle one-quarter wavelength apart.

Line loss effects

Figure 3 above shows what would happen to the VSWR circle when loss is intro-

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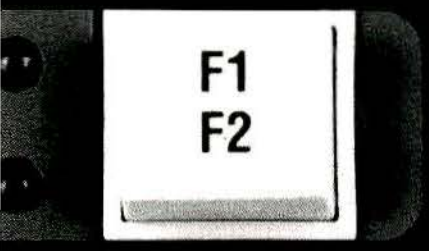

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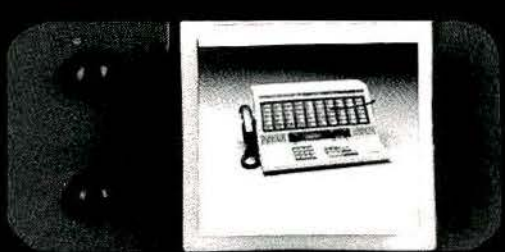

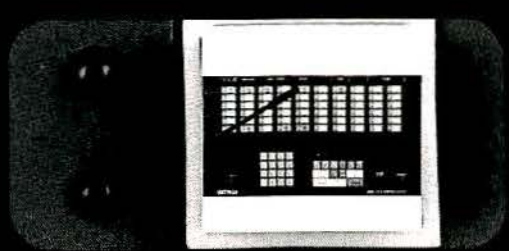

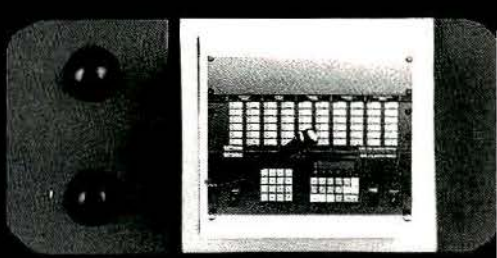

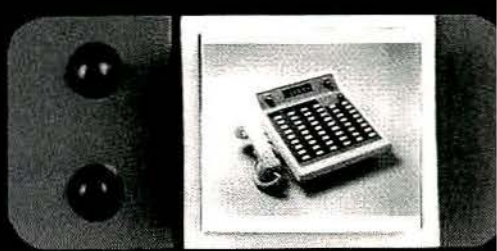

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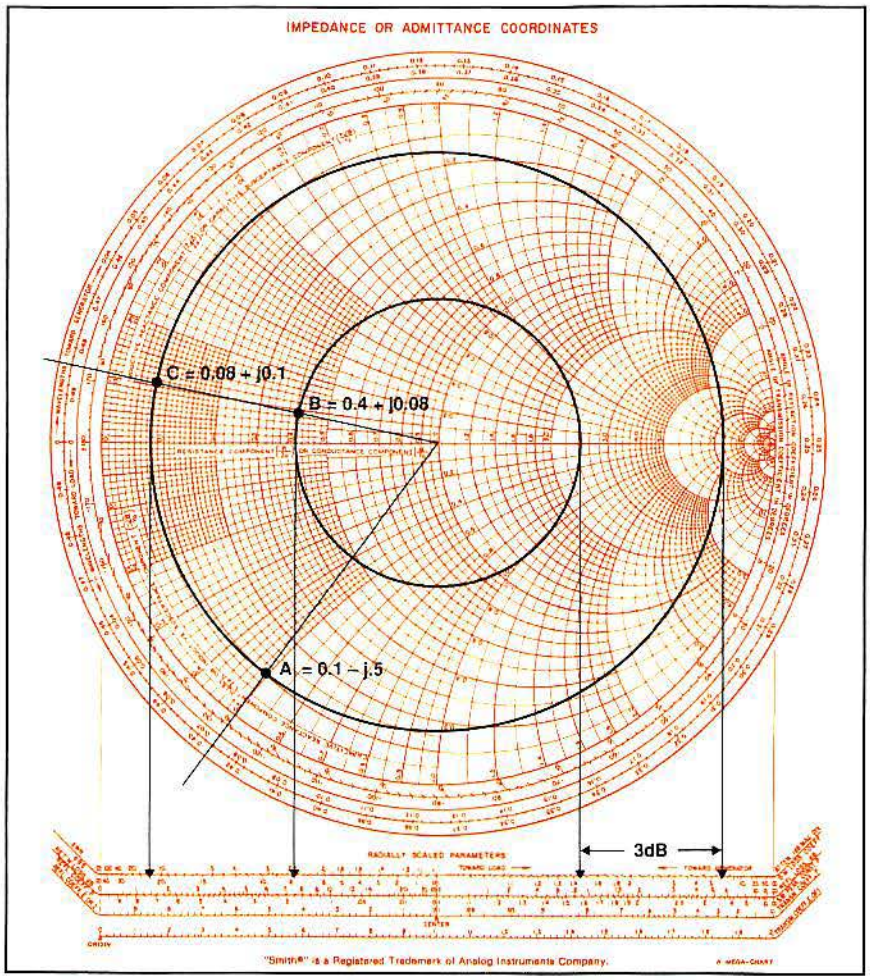

Figure 5: This chart shows the effect of line loss on impedance and VSWR. See text for details.

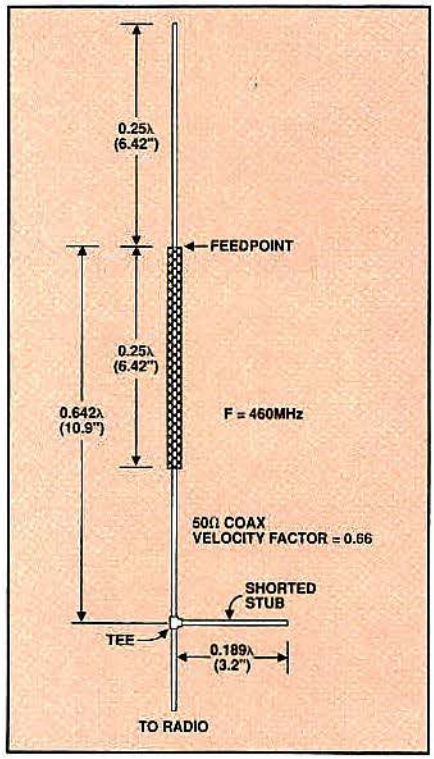

Figure 6: This antenna is made by folding a quarterwave section of braid (shield) back over the outer jacket. The center conductor serves as the other half of the halfwave dipole. The antenna is 75Ω at the feedpoint, and the coaxial line is 50Ω. The Smith chart in Figure 7 is used to determine the proper location and length of a shorted stub to match the 75Ω antenna to the 50Ω system.

duced into the picture. Refer to the drawing in Figure 3 and the Smith chart in Figure 4 on page 62. Figure 3 shows that a 50Ω system is terminated in a pure resistance of 16.7Ω (16.7 ± *j*0)Ω. This is normalized to (0.33 ± *j*0). This is the starting point (point of entry) on the Smith chart at Point L. One-quarter wavelength away toward the load, an attenuator (A1) is placed in the line.

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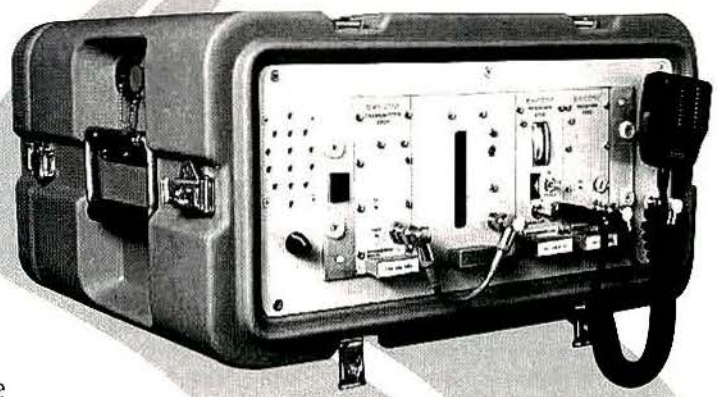

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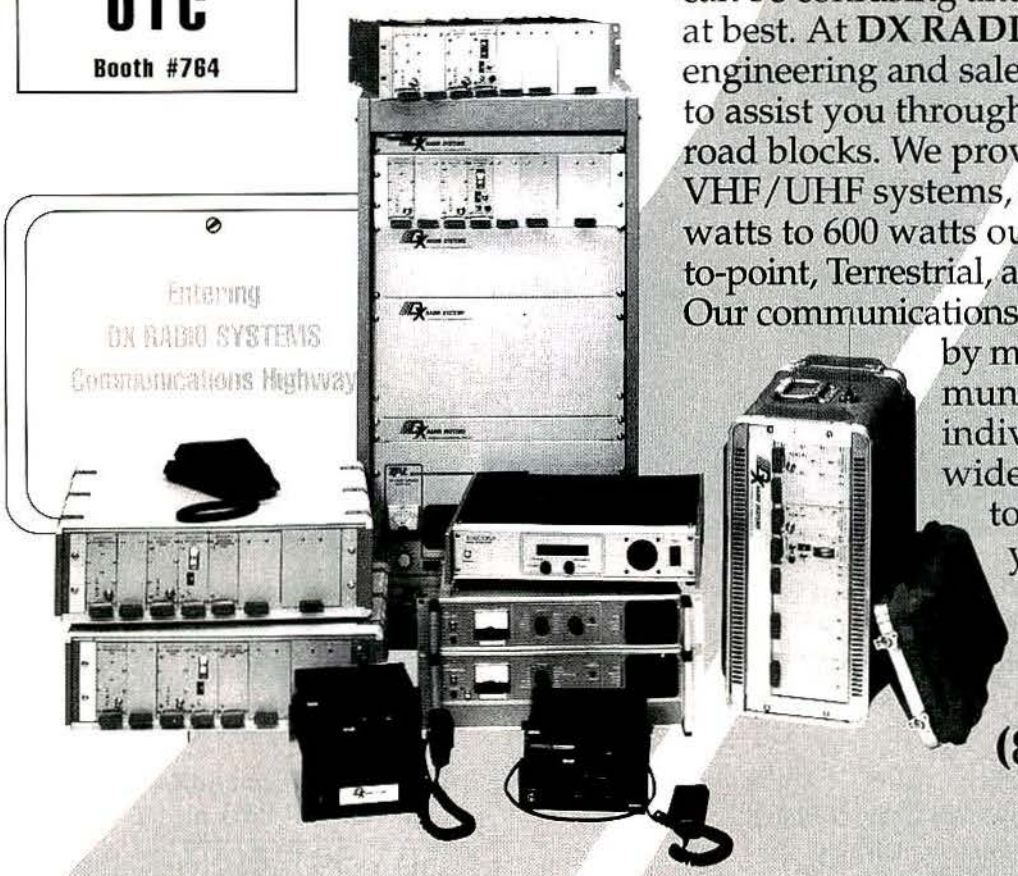

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Table 1—These are the points on Figure 1, along with the equivalent values of complex impedance, complex admittance, and the normalized values of both Z_N and Y_N.

POINT LOCATION	Z_N OR Y_N	50Ω SYSTEM Z	20mS SYSTEM Y
A	(1.0 + j2.0)	(50 + j100)	(.02 + j.04)
B	(2.0 + j1.0)	(100 + j50)	(.04 + j.02)
C	(1.0 + j0.5)	(50 + j25)	(.02 + j.01)
D	(0.5 + j0.2)	(25 + j10)	(.01 + j.004)
E	(0.0 + j0.0)	(0 + j0)	(0 ± j0)
F	(0.2 − j0.5)	(10 − j25)	(.004 − j.01)
G	(0.5 − j1.0)	(25 − j50)	(.01 − j.02)
H	(2 − j2)	(100 − j100)	(.04 − j.04)

Notice the abrupt change in the circle at A1. Another quarter-wavelength away, a second attenuator (A2) is placed in the line. Again, there is an abrupt change in the circle. The circle changes at each attenuation point, drawing closer to the center each time an attenuation is encountered.

Transmission lines cause attenuation. However, the attenuation on a transmission line is smooth and evenly distributed throughout the length of the line rather than in lumped forms as depicted by Figures 3 and 4. Thus, the change in the VSWR circle will not be abrupt as shown in Figure 4, but will constantly change in *infinitely smaller increments*, resulting in a smooth, spiral-shaped plot.

Normally, we are not interested in what the impedance or admittance is at every point on a transmission line. Thus, the spiral is not necessarily always of interest. Study the following example:

A transmission line is terminated by an impedance of $(5 - j25)\Omega$. The system impedance is 50Ω. The line length is 100 feet, and the line loss is 3dB/100 feet at the operating frequency of 150MHz. The velocity factor of the line is 0.66. Use the Smith chart to determine what the impedance will be at the transmitter (generator) 100 feet away from the load. What is the VSWR at the load? What is the VSWR at the transmitter? Refer to Figure 5 on page 64.

First, we need to determine how long the transmission line is in terms of wavelengths. The formula is:

$$L = \left(\frac{984.3V}{F}\right) = \left(\frac{984.3(0.66)}{150}\right) = 4.33$$

where

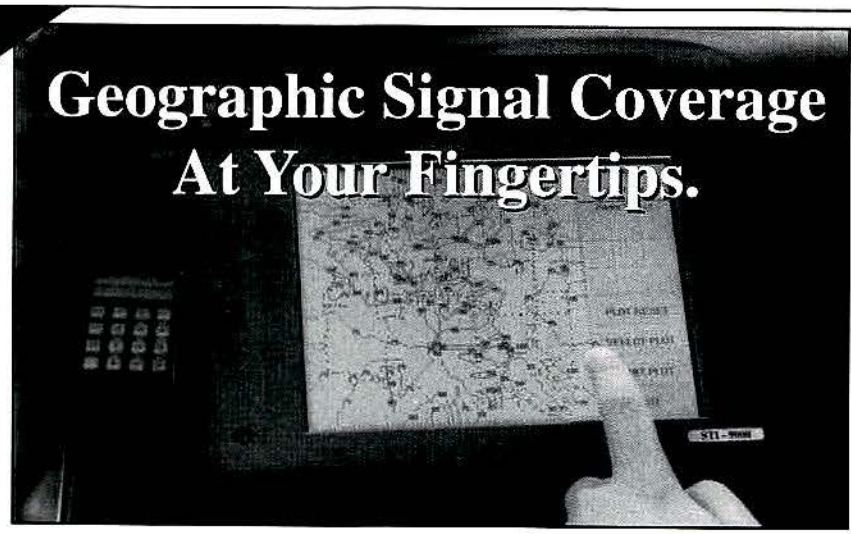
L = wavelength in feet

V = velocity factor

F = frequency in MHz

Thus, the line contains 100/4.33 = 23.09λ. Throw away the 23, and keep the decimal part (0.09λ).

Next, we normalize the load impedance $(5 - j25)$ to $(0.1 - j0.5)$. We enter the Smith



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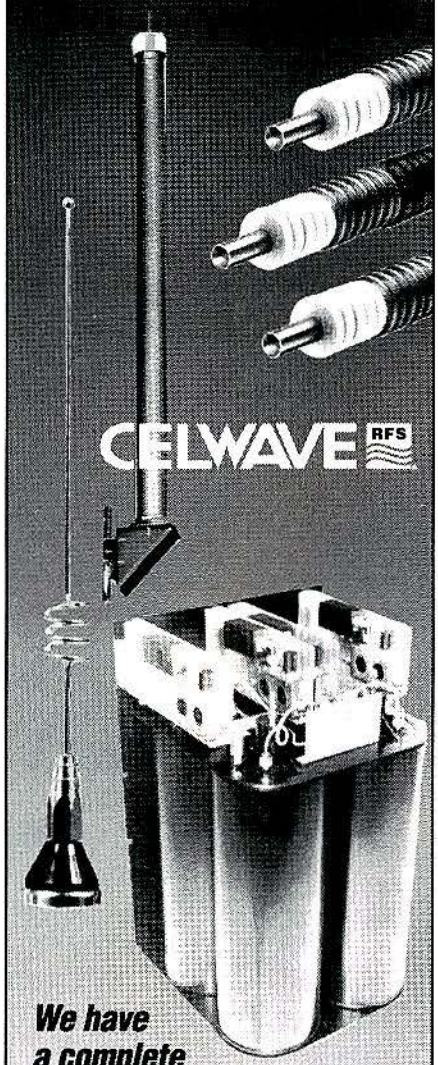

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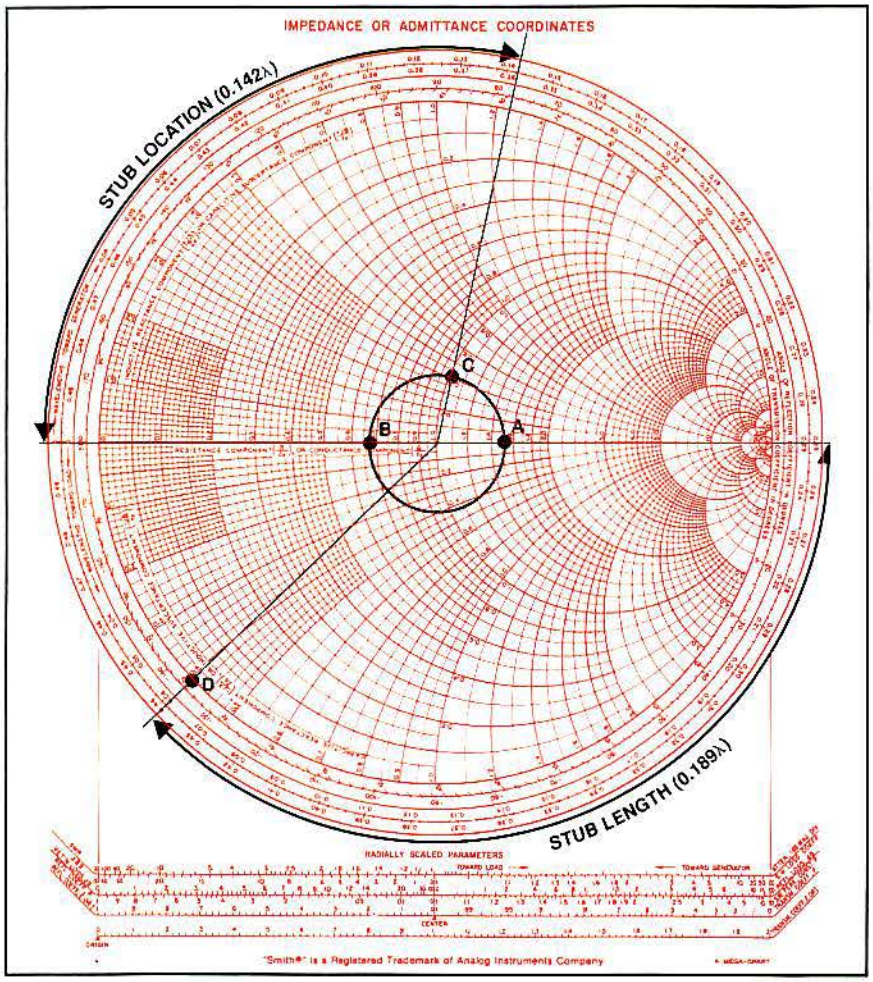

Figure 7: This Smith chart is used to find the correct length of a shorted stub and the proper location to effect an admittance match (impedance also) for the antenna shown in Figure 6.

chart at Point A and draw a VSWR circle through Point A. From Point A to Point C on the outer circle represents a move of 0.09λ on the line toward the generator (transmitter). The wavelength is read on the outer scale. Notice that the line through the reference A (point of entry) extends through the 0.426λ point on the outer scale. Now add 0.09λ to 0.426 to get 0.426 + 0.090 = 0.516λ. Because the scale does not go past 0.5λ, subtract 0.5 from 0.516 to get 0.016λ. Draw a line from the origin to the outer scale at 0.016λ. Where the line intersects the outer circle is the impedance at the transmitter for a lossless line. However, our line has a 3dB loss from end to end.

To take the loss into account, a new VSWR circle must be drawn. This is done as shown in Figure 5. A line is drawn from the first (lossless) VSWR circle down to the radial attenuation scale. Using dividers, 3dB is marked off on the scale, and then a line is extended upward to the horizontal axis. A new circle is drawn tangent to the point of intersection of the horizontal axis and the line extending from the 3dB attenuation point. The impedance at the transmitter is found at Point B on the second (inner) circle. The normalized value is $(0.4 + j0.08)$. The actual impedance is: $50(0.4 + j0.08) = (20 + j4)\Omega$.

The VSWR at the load is shown by the line extending from the outer circle on the left down to the radial VSWR scale at 12.25:1. The VSWR at the transmitter is shown by the line extending from the inner circle on the left down to the radial VSWR scale at approximately 2.4:1.

VSWR and complex impedance

VSWR is easy to calculate when the load is a pure resistance (not a complex impedance). It is simply Z_L/Z_0 or Z_0/Z_L, whichever is the larger. However, when the load contains a *reactive* component, the formula becomes more complicated. The formula is:

$$VSWR = \left(\frac{1+\Gamma}{1-\Gamma}\right)$$

where

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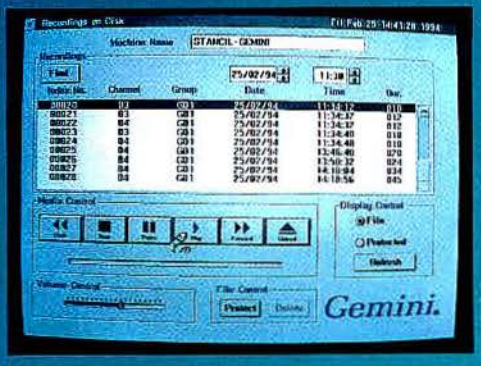

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Charting the unseen

Phillip H. Smith, a descendant of another American innovator, Eli Whitney, was born in 1905 in Lexington, MA. An amateur radio enthusiast while attending college, Smith graduated from Tufts University, Medford, MA, in 1928 with a B.S. in electrical engineering. He immediately began an association with Bell Telephone Laboratories that would last 42 years.

In 1929, Smith became intrigued with matching the impedance between a transmission line and an antenna. By 1936 he had devised a rectangular plot solution, which he evolved into a chart in polar coordinate form. This allowed all values of impedance to be accommodated. The impedance coordinates were not orthogonal, nor true circles, but the VSWR was linear.

Phillip H. Smith

Smith suspected that a grid system of orthogonal circles might be more practical and reproducible as a chart. Co-workers E.B. Ferrell and J.W. McRae helped him apply conformal mapping techniques to transform the chart to a grid that used orthogonal circles. This transformation accommodated all data from zero to infinity. This prototype chart created in 1937 is essentially the form still in use.

The Smith chart was not an overnight success. With few professional journals available, it was two years before the method was first published in *Electronics* magazine. A.G. Fox of Bell Labs used it as a tool for his early work on waveguides in 1939, and in 1940 the M.I.T. Radiation Laboratory became Smith's first "customer" for the chart. By 1975, that first sale would grow to about 9 million copies.

Smith made numerous contributions to electronics. Prior to World War II, he designed antennas and other components for SCR-268 radar. He later worked on early microwave antennas for submarines.

After the war, Smith designed FM broadcast antennas for Western Electric and invented the cloverleaf antenna. Twenty U.S. Patents related to antennas and microwaves bear Smith's name, including the basic patent for the adjustable stub tuner.

Later work on military radar systems included electrical design supervision for the DEW (Distance Early Warning) Line and Safeguard programs.

Smith eventually published more than 35 technical articles. His major contribution is covered in his book, *Electronic Applications of the Smith Chart.*

Retiring from Bell Labs in 1970, Smith, also a private pilot, started Analog Instruments of New Providence, NJ, to merchandise navigational instruments for light aircraft—and to supply his charts. The company continues, operated by his widow, Anita M. Smith. Phillip Smith died in 1987, aged 82.

Smith was made a fellow of the IRE in 1952, but his first professional award came after his retirement. The Microwave Theory and Techniques Society of the IEEE presented him its 1975 Special Recognition Microwave Application Award for the invention and application of the Smith chart.

$$\Gamma = \left(\frac{Z_L - Z_o}{Z_L + Z_o}\right)$$

where Z_L is in complex form

Using this formula, we can calculate the VSWR for the complex impedance represented by Point B in Figure 5. The actual impedance at Point B is $50(0.4 + j0.08) = (20 + j4)\Omega$. First, we find Γ by substituting the impedance values into the formula.

$$\Gamma = \left(\frac{20-j4-50}{20-j4+50}\right) = \left[\left(\frac{-30-j4}{70-j4}\right)\left(\frac{70+j4}{70+j4}\right)\right]$$

$$= \left(\frac{-2{,}084-j400}{4{,}916}\right)$$

$$= (-0.4239 - j0.0814)$$

$$\Gamma = \sqrt{0.4239^2 + 0.0814^2} = \sqrt{0.1863} = 0.4317$$

Now, the VSWR is:

$$VSWR = \left(\frac{1 + 0.4317}{1 - 0.4317}\right) = 2.52$$

Impedance and admittance matching

The Smith chart is useful in designing stub-matching arrangements to match a mismatched load to a transmission line. In his book *Electronic Applications of the Smith Chart*, Smith writes:

"The single open- or short-circuited shunt matching stub whose length is continuously adjustable over a range of one-quarter wave-

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length, and whose position along the main line is adjustable over a range of one-half wavelength, is capable of correcting any mismatched condition whatsoever along the main line."

Let's put this statement to practical use with the Smith chart.

Figure 6 on page 64 shows how a halfwave dipole can be made by folding the braid back over the outer jacket of a length of 50Ω coaxial line. The problem is that this antenna would have an impedance of 75Ω (75 ± *j*0)Ω if properly cut for the operating frequency. We know that we can place a stub (open or shorted) of the *proper length* on the line at the *proper location* and effectively match the 75Ω antenna to the 50Ω system impedance.

The problem is then reduced to finding the right length of stub (shorted or open) and *the right place to put it*. This is where the Smith chart *shines*. Refer to the Smith chart in Figure 7 on page 68. The antenna impedance is (75 ± *j*0)Ω. We must match this impedance to the 50Ω system impedance. Because we are dealing with a shunt stub, it will be easier to work with admittance instead of impedance. If we effect an admittance match, the impedance also will match.

The impedance (75 ± *j*0)Ω is normalized to (1.5 ± *j*0) at Point A on the Smith chart in Figure 7. A VSWR circle is drawn tangent to this point. Next, a line is drawn from the origin to intersect the VSWR circle at Point B. The intersection of this line and the VSWR circle is the equivalent normalized admittance of the impedance (75 ± *j*0). The normalized admittance at Point B is (0.67 ± *j*0)S. Next, we look for a point where the VSWR circle intersects the *unity resistance* circle. This is Point C on the chart. Next, a line is drawn from the origin through Point C and on through the outer wavelength scale. The difference on the wavelength scale between Points B and C is the distance from the load in wavelengths where the matching stub must be placed. As shown in Figure 7, this is 0.142λ.

The next problem is to calculate the length of the stub. Because we are going to use a shorted stub, we use the infinity admittance point at the far right of the horizontal axis as the reference point. This represents the shorted end of the stub. (A short exhibits 0 impedance. Because admittance is the reciprocal of impedance, then the admittance is 1/0 or infinity.)

The normalized admittance at Point C where the stub is to be located is (1 + *j*0.4). We want the normalized admittance at that point to be (1 ± *j*0). In order to achieve this we must add a normalized admittance of (0 − *j*0.4). This point is located at D of Figure 7. A line is drawn from the origin through Point D and on through the outer wavelength scale. The difference between Point D and the infinity admittance reference on the wavelength scale is the length of the shorted stub in terms of wavelength. This difference is 0.189λ.

$$C = 1 + j0.4$$
$$D = 0 - j0.4$$
$$\text{Resultant} = 1 \pm j0.0$$

The distance of the stub from the feedpoint was 0.142λ. As it turns out, this is too close to the antenna feedpoint because it would be under the folded-back braid. (The braid is 0.25λ long.) We can get around this problem by simply adding another one-half wavelength (0.5λ) to the distance. Remember, impedance and thus admittance repeats every 0.5λ. Adding 0.5λ would place the stub at 0.142 *plus* 0.500 = 0.642λ. The actual distance *in inches* is computed as follows:

$$L = \left(\frac{11{,}811(V)(\lambda)}{F}\right) = \left(\frac{11{,}811(0.66)(0.642)}{460}\right)$$
$$= 10.89 \text{ inches}$$

where

L = length in inches

V = velocity factor

λ = wavelength

F = frequency in MHz

From Figure 7, the stub length is 0.189λ. This is computed just as the stub location was:

$$L = \left(\frac{11{,}811(0.66)(0.89)}{460}\right) = 3.2 \text{ inches}$$

The final results of the Smith chart work are shown in Figure 6. The accuracy depends upon careful interpretation of the coordinates on the Smith chart.

Although this material has only scratched the surface of the Smith chart, it is hoped that some insights into the basic uses of the chart have been provided here. *Stay tuned.*

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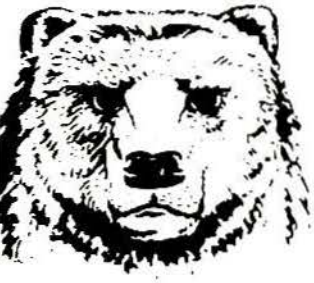

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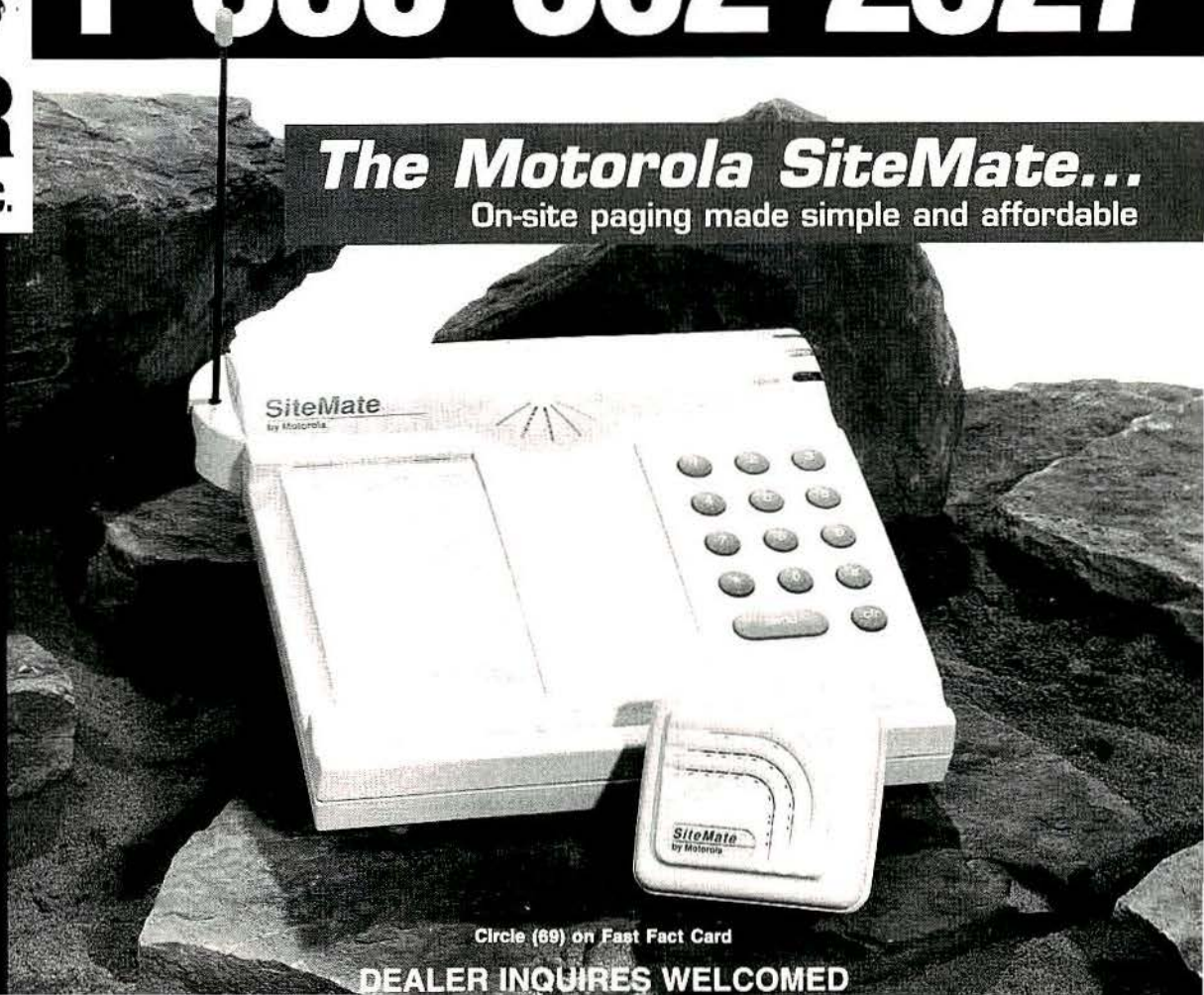

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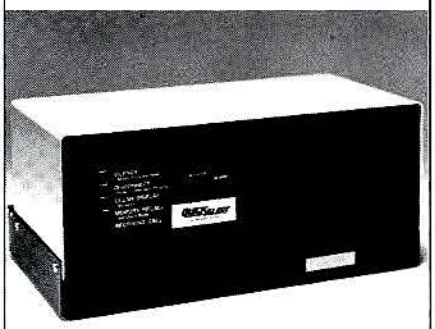

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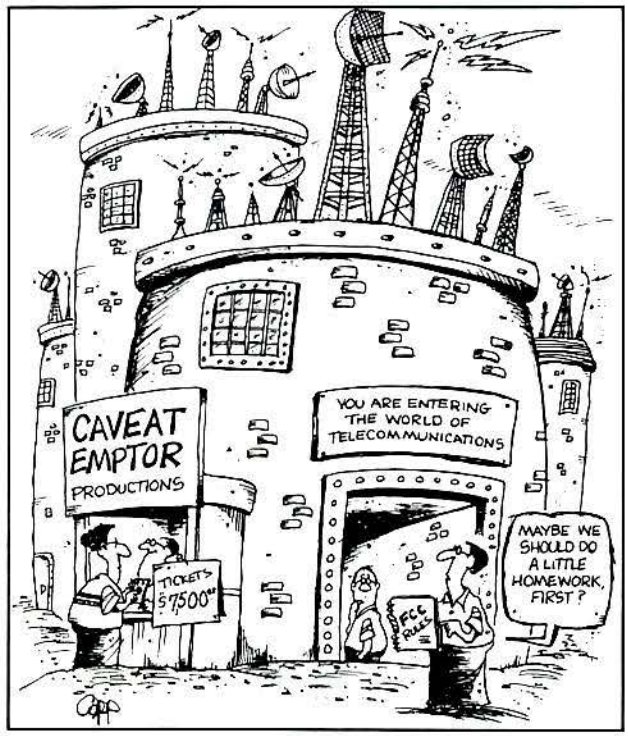
Spectrum junk bond traders

By Robert H. Schwaninger, Jr.

Remember the 1980s? Wall Street was booming under a blizzard of junk bond traders that made fortunes selling paper. Okay, the paper was supposed to be a security instrument that entitled the bearer to great returns—provided that the issuer made money, could pay its bills and could service the billions of dollars in debt created by issuing the paper in the first place.



Despite the questionable value of this paper, the big and the small rushed to grab a fistful. After all, the money raised by trading in these slips was to be used to buy major industrial giants, high-tech firms and anything and everything that could be raided, sliced, diced and leveraged to create more of the slips of paper.

Welcome to the 1990s, where licenses have replaced junk bonds in the world of trading. Now, speculators, investors and people who don't know a radio from a radish have rushed forward to strike it rich in telecommunications. Application mills have replaced storefront brokerage houses and even your Uncle George has his own piece of the radio spectrum by simply dialing "1-800-FASBUCK."

One area where this activity has been particularly prevalent is SMR spectrum. The "infomercials" shown on late night cable have convinced thousands of otherwise intelligent Americans that for a mere $7,500, they too can be part of the next telecommunications bonanza; and most of them actually got a real, suitable-for-framing license from the FCC.

All right, so the newly licensed telecommunications tycoon lives in San Diego, and the license is for a single channel GX facility in Catawissa, Pa. No matter. We, the members of the industry, know that buyers will beat a path to the fresh licensee's door, offering barrels of bucks and begging for a chance to buy the newly issued authorization. R-i-i-ght!

Unfortunately, that's exactly what these investors believed would happen. So they sat and waited and waited. Strangely, the phone never rang. Then one day they received an offer from another company. The company will construct and manage their system and split the revenue with them. The investors are encouraged to sign these deals by being supplied with a vital piece of information—if they don't construct the system within eight months from grant, their license cancels automatically, and their investment is worthless.

Panic sets in. They sign. A review of what they just signed by an experienced eye would reveal that the document is highly questionable. First, it likely does not conform with the FCC's guidelines for such agreements. Second, it probably includes consent to future short-spacing of the system by anyone the manager chooses. Finally, the manager is probably affiliated with the company that sold the investor the application mill services in the first place.

In the largest fast shuffle of this kind, companies named Metropolitan, Columbia and Nationwide (was "Acme" taken?)

Schwaninger, MRT's regulatory consultant, is a partner in the law firm of Brown and Schwaninger, Washington, DC. He is a member of the Radio Club of America.

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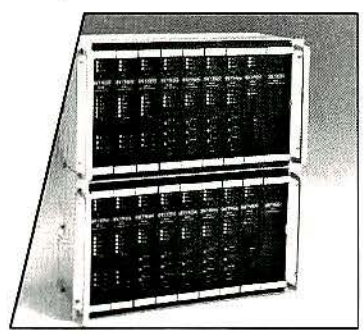

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convinced about 4,000 people to take a ride. Each one of the people would become SMR licensees in hopes of getting rich in a hurry. Their motivation was greed, and in the food chain of telecommunications the even greedier applications mills ate each of these smaller fish.

Let's make one thing clear. I'm in favor of greed. It makes markets sing, puts people to work, raises the standard of living and generally is the stuff of a healthy economy. However, even greed must be tempered with reason. One axiom which springs to mind is, "You pay your money and you take your chances."

But that axiom is sometimes lost in our society, which is filled with people who do not wish to take responsibility for their own actions. I support the Federal Trade Commission's efforts against the allegedly underhanded actions of the application mills and their questionable claims. You could support any investor who has demanded that their system be constructed by the management company or who has taken steps to get any refunds due and owed from hustlers. What can not be supported is the most recent request placed before the FCC by these alleged victims.

On March 21, the court-appointed receiver for Metropolitan Communications, Nationwide Digital Data, Columbia Communications and Stephens Sinclair (presumably all affiliated in the application mill business) requested that the FCC waive its rules to allow additional time for the 4,000 or so licensees to construct their systems. The receiver claims that without the waiver, these licensees are likely to be left with canceled authorizations, rendering their investments worthless.

On first blush, this request might appear to be justified by the soft-hearted who would not like for Uncle George to lose his $7,500. But one should not be too quick to rush to the receiver's aid. In truth, the receiver is likely trying to limit the claims against the companies in receivership from licensees who were never told that they had to construct within eight months. By getting additional time, the receiver might be able to convince some legitimate operators to construct and manage some of the systems.

Let's not forget about the "poor" licensees. Even assuming that these people were defrauded by these companies, they are far from innocent. Each signed an FCC Form 574, acknowledging their responsibility to obtain a copy of the FCC Rules. Each requested to become a Commission licensee, ostensibly with the intent "to provide telecommunications service to the public." Each acted in ignorance, motivated by greed.

No one is going to convince any reasonable member of the telecommunications community that the "1-800" speculators considered this opportunity to be anything more than a get-rich-quick scheme. That such people are extremely vulnerable to the charlatans of this world is unfortunate, but self-inflicted. The numbers racket has thrived on such people for years, and no "pigeon drop" con ever worked without a little larceny in the heart of the victim.

What the FCC and the industry should stand up for is application of the same standards for everyone. A license should mean that the licensee intends to construct, operate and render a service. Licenses should not become mere junk bonds to be shuffled about by persons who are only serious about making easy money and not serious about providing services to the public. Radio spectrum is scarce and precious and should not be degraded by tactics which keep its availability out of the hands of legitimate operators and manufacturers.

By application of equal standards, at least 4,000 SMR channels would become available for expansion of legitimate systems and for integration into ESMR operations, without the need to pay tribute to the present licensees. That is what should happen. The licensees paid their money, took their chances—and lost.

This situation is another unfortunate chapter in the history of application mills. Adding to the sorry history is the fact that, thus far, the FCC has taken no steps to prevent future reoccurrences of the same situation. As long as application mills are allowed to operate, abuses will occur. The only way to prevent this harm is to enforce the FCC Rules which state that only applicants and their legal representatives may prepare and file applications.

Meanwhile, legitimate operators may wish to wait for the flood of cancellations which we hope will begin after denial of the waiver request. With each cancellation will come an opportunity for legitimate operators to improve their systems and their businesses. Freed from the stymie of spectrum shortage caused by these pseudo-licenses, the SMR industry will be provided a fresh supply of spectrum. On the other hand, the recaptured spectrum might just become inventory for another application mill.

If so, pity the public.

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Circle (72) on Fast Fact Card

Motorola advances efforts in wireless communications

Contracts, products, services and field test results involving various Motorola business units, their customers and cooperating manufacturers are advancing wireless communications in several areas of technology.

▶ The Land Mobile Products Sector, Schaumburg, IL, will provide $187 million worth of digital radio communications equipment and services for the Michigan State Public Safety Communications system.

▶ The Land Mobile Products Sector has begun selling mobile data services provided by Racotek, Minneapolis.

▶ The Synapps Business Unit, Schaumburg, IL, has an alliance with Dataradio, Atlanta, to distribute synthesized RNet radio modem and telemetry products for the 450MHz band.

▶ The Paging Products Group, Boynton Beach, FL, has completed six months of tests of its Flex high-speed paging protocol, using facilities in Kansas City, MO, owned by Paging Network, Plano, TX. Similar tests were conducted in Wichita, KS, on facilities owned by AirTouch Communications, Walnut Creek, CA.

▶ The Paging Products Group teamed again with Paging Network to develop a portable wireless answering machine using Motorola's Keynote pager. A prototype is being marketed as VoiceNow in Las Vegas.

▶ The Paging Products Group is sponsoring TV broadcasts of 14 major league baseball teams in a combination of regional cable network, superstation and spot TV commercials.

▶ The Paging Products Group is developing systems and products for narrowband personal communications services (PCS) spectrum, including products for the nationwide wireless network (NWN) to be built by Mtel, Jackson, MS. Portable equipment will include PCMCIA cards and stand-alone messaging devices.

▶ The Customer Owned Paging Operation, Boynton Beach, FL, is integrating its on-site paging systems with the CallXpress voice processing system made by Applied Voice Technology, Kirkland, WA.

Auto-Trac to build AVL system for county public transit service

Auto-Trac, Dallas, has been awarded a public transit contract for the County of Lackawanna Transit System (COLTS) in Scranton, PA. This custom-designed system is one of the first AVL systems for public transit in which the vehicle tracking unit can initiate the "next stop" announcement system.

The Fleetservice system customized for the public transit system is composed of a communications controller, one or more mapping computers, vehicle tracking units and two-way communications via mobile data terminals.

In addition to the standard features, the Auto-Trac Fleetservice is providing COLTS the following: differential Global Positioning System (GPS) tracking, GPS-triggered "next stop" announcement system, on-time schedule monitoring, multiple mapping stations controlled by a local area network and a replay feature to play back the movement of any bus for any given time and date.

SMR operator urges FCC to revoke Nextel licenses

A specialized mobile radio (SMR) system operator in Florida has petitioned the FCC to revoke SMR licenses held by Nextel, Rutherford, NJ.

Kevin Lausman, who operates SMR systems in competition with Nextel in Tampa, St. Petersburg and Clearwater, FL, lists flaws (such as insufficient details identifying Nextel's licenses) in a previously filed Nextel petition for a waiver of FCC rules to allow foreigners to own its stock and to have foreign citizens on its board of directors.

Lausman's "opposition" petition notes that Nextel anticipates increasing or changing the amount of foreign ownership in the company, and that future changes are not allowed under the FCC's rules for foreign ownership of a common carrier or commercial radio service operator. Lausman claims that, even if the FCC were to allow certain foreign ownership and directors as of the date of Nextel's request, subsequent increases in foreign ownership would render Nextel ineligible to hold SMR licenses.

Lausman's petition also describes information Nextel supplied to the Securities and Exchange Commission as contradictory to information supplied to the FCC. The petition contends that because of the alleged contradictions, Nextel may lack the character qualifications to remain an FCC licensee.

Electronics consortium plans for the commute of the future

A consortium involving consumer and electronics industry giants has received $5.5 million in state and federal funds to test a high-speed FM subcarrier data broadcast system for disseminating en-route information to consumers through affordable, reliable, multi-use devices. The long-term goal of the test is to help drivers and commuters determine the most time-efficient and cost-effective ways to reach their destinations and to reduce congestion on the country's busy streets and highways.

The group, called the Seattle Consortium for IVHS (Intelligent Vehicle Highway Systems) Technologies, consists of International Business Machines (IBM); Delco Electronics; Seiko Telecommunication Systems; the Washington State Department of Transportation; the University of Washington; the King County Department of Metropolitan Services; Etak; and Metro Traffic Control.

Familiar mass market products will be used to make the following types of information available:

- descriptions of major traffic incidents, road construction sites and major highway lane volume.
- city maps with mass transit vehicle locations.
- car navigation information based on a global positioning system.
- route schedule for buses, ferries and other mass transit options.
- automated ride-share programs that match people to car pools.
- personal information services (paging, messages, weather forecasts, sports scores, ski condition reports, winning lottery numbers, etc.) for keeping people in touch when on the go.

The two-year test, worth more than $7 million, will add traffic and commute services to existing products, rather than create new, dedicated, single-function IVHS products that can be costly to consumers.

The devices under the consortium test will receive and display data from FM subcarrier radio signals. The communications backbone that will transmit data for the IVHS test is the High Speed Data System (HSDS) wireless networking protocol developed by Seiko Telecommunication Systems, and this FM subcarrier-based network will transmit traffic and commute information to devices housing the Advanced Communications and Timekeeping Technology (ACTT) data receiver chip set, also developed by Seiko. The consumer devices that will incorporate the ACTT data receiver chip set as part of this test include an IBM portable computer, a Delco Electronics in-vehicle radio receiver and the MessageWatch from Seiko.

Broadcast tower builder introduces line of small towers

Stainless, North Wales, PA, a company that has built many of the nation's TV transmitter towers, is expanding its line of small towers. The Stainless companies, Stainless and SG Communications Services, are offering a new line of towers for SMR, cellular and other wireless communications applications.

The companies provide design, fabrication, AISC-certified quality control and installation of all new small tower configurations and monopoles, as well as systems integration using analog and digital systems; conventional and trunked two-way systems; cellular, radio and paging systems; and antenna systems. Inspection services and maintenance programs, including 24-hour emergency service, are available.

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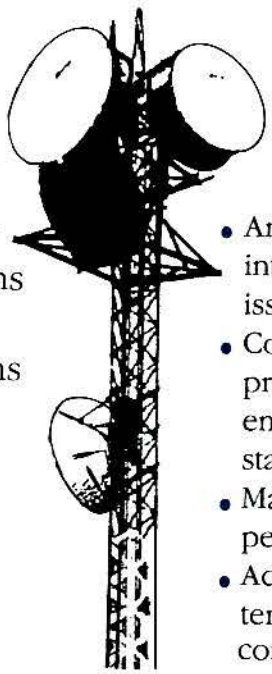

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Glenayre, PacTel install Hark's enhanced Tap 200

PacTel Paging's Michigan office was the site for the recent test in which alphanumeric text concentrated through the Tap 200 was sent over Type 2 lines using the "Switch Through" feature of the GL 3000 paging switch manufactured by Glenayre, Duluth, GA.

"We believe this solution will enable paging providers to avoid using costly 800 lines and cut monthly phone bills in half," said Randy Hargenrader, president of Hark Systems, Summerville, SC.

The enhanced version of the Tap 200 will permit alphanumeric text over regular DID lines and will offer paging operators greater "economy of concentration." It also has built in TDD access, which is becoming more important as operators move toward compliance with the Americans with Disabilities Act.

Moducom installs communications control system for Navajo Nation

Modular Communications (Moducom), North Hollywood, CA, has completed installation of a mobile radio communications control system for the Navajo Tribal Utility Authority (NTUA) of the Navajo Nation, Fort Defiance, AZ. The NTUA provides water, power and gas for the 25,000-square mile Navajo Nation, and the system will be used in conjunction with the NTUA's emergency services and dispatching operations.

Eight Moducom Ultra-Com Pro workstations are being used, one at the Fort Defiance headquarters with the main electronics package (MEP), and at seven locations within the Nation. The remote stations are connected to the MEP via a digital microwave link.

PageNet to offer non-paging service on nationwide network

PageNet, Dallas, has been selected to provide local, regional and nationwide wireless data and messaging services for the new HP StarLink service from Hewlett-Packard, Spokane, WA. This service is the first use of PageNet's nationwide digital network to transmit wireless messages to devices other than pagers. HP StarLink electronically delivers e-mail, voice and data messages to HP 100LX palmtop computers.

PageNet completed the construction of its nationwide digital transmission network Nov. 29, 1993, and immediately began offering a new nationwide paging service announcing that transmission of other wireless data services would follow.

Qualcomm, Schlumberger sign test equipment license agreement

Qualcomm, San Diego, and Schlumberger, New York, have signed a test equipment license agreement. Under the agreement, Schlumberger will be able to manufacture and sell infrastructure and subscriber test equipment based on Qualcomm's code division multiple access (CDMA) technology to markets worldwide.

"The growing interest in CDMA is expected to create increasing markets for CDMA products in cellular, Personal Communications Services (PCS) and wireless local loop applications," said Allen Salmasi, executive vice president and general manager for wireless communications at Qualcomm. "Providing high-quality RF test equipment is essential in assuring smooth commercial deployment of this technology."

Plans for the first commercial service of CDMA have been announced by US West New Vector Group for its Seattle cellular market in early 1995. Other carriers that have announced CDMA implementation plans include Nynex, AirTouch Cellular, GTE Mobilenet and Alltel Mobile.

Also, the Korean Ministry of Communications has selected CDMA for the Korean telephone system's 1995 digital transition, and Extelcom, a Philippine national cellular carrier, plans a 1995 implementation of CDMA.

Prairie Village, KS, moves toward area-wide communications network

The city council of Prairie Village, KS, unanimously voted to purchase an Enhanced Digital Access Communications System (EDACS) from Ericsson GE Mobile Communications, Lynchburg, VA. With the new system, Prairie Village will be able to directly communicate with the adjacent communities of Overland Park, KS, on the west and Kansas City, MO, on the east, both of which previously purchased wide-area EDACS networks.

The Prairie Village System will be used by all city departments and will use Ericsson GE's new C3 Maestro CRT consoles.

AirTouch Communications separates from Pacific Telesis Group

AirTouch Communications, Walnut Creek, CA, formerly PacTel, has completed its spin-off from Pacific Telesis. AirTouch subsidiaries will operate under the new names of AirTouch Cellular, AirTouch Paging and AirTouch International.

AirTouch Communications plans to expand service into new customer segments and enter new overseas markets. The company is pursuing CDMA, Cellular Digital Packet Data (CDPD) and Personal Communications Services (PCS), and the company intends to bid on licenses that will be auctioned by the FCC.

AirTouch also plans to continue to enter into strategic alliances, such as its recently announced plans to invest in the Globalstar satellite venture, where such partnerships make sense to expand service or develop a new technology.

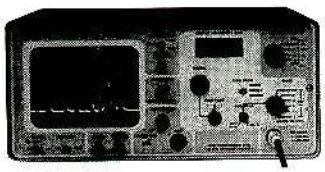
AVCOM's New PSA-65A Portable Spectrum Analyzer

The newest in the line of rugged spectrum analyzers from AVCOM offers amazing performance for only **$2,855.**

AVCOM'S new **PSA-65A** is the first low cost general purpose portable spectrum analyzer that's loaded with features. It's small, accurate, battery operated, has a wide frequency coverage - a must for every technician's bench. Great for field use too.

The **PSA-65A** covers frequencies thru 1000 MHz in one sweep with a sensitivity greater than –95dBm at narrow spans. The PSA-65A is ideally suited for 2-way radio, cellular, cable, LAN, surveillance, educational, production and R&D work. Options include frequency extenders to enable the PSA-65A to be used at SATCOM and higher frequencies, audio demod for monitoring, log periodic antennas, 10KHz filter for .2 MHz/DIV range, carrying case (AVSAC), and more.

For more information, write, FAX or phone.



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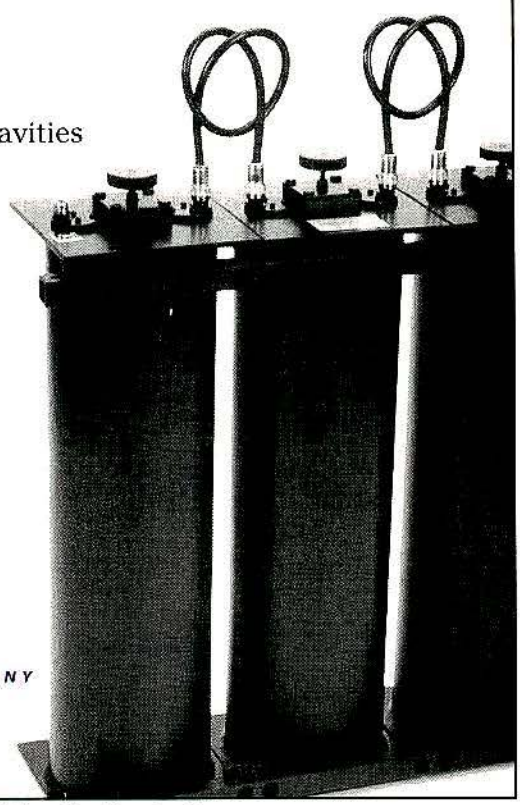

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Circle (75) on Fast Fact Card

Readers' choice

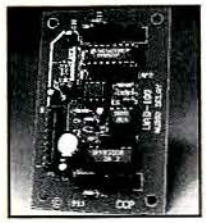
Of all the new products and services in the October 1993 issue, the ones reprinted here generated the most reader requests for additional information. If you missed them the first time, here is your opportunity to acquire more information on them. Just circle the corresponding Fast Fact Card number on the card found in the back of this issue and mail the card to us.

GPS board is credit card-size

NavCore MicroTracker from **Rockwell International** is a five-channel GPS receiver that measures 2" × 2.8" × 0.53" and weighs two ounces. The MicroTracker can be used in personal communicators, AVL equipment or mobile data terminals. The MicroTracker operates with an inexpensive passive antenna in most applications, allowing OEMs to reduce production costs of their end products. Available as an option with the new module is RTCM SC-104 compatible differential GPS, which improves accuracy to five meters over 95% of readings.

Circle (500) on Fast Fact Card

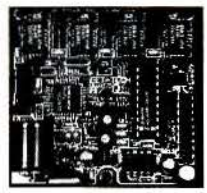
Fully assembled audio delay board features complete DTMF tone mute



The UAD-100 universal audio delay board is inserted in the repeater receiver audio path before any audio switching circuitry to delay the audio before it arrives at the repeater transmitter. The unit, from **Creative Control Products**, features DTMF tone mute and squelch tail elimination. It comes assembled and tested with a detailed application manual and a one-year warranty.

Circle (501) on Fast Fact Card

Digital voice recorder RAM storage holds 3½ minutes of speech



The AudioQ-218 digital voice recorder records as much as 218 seconds of speech. With four selectable sample rates standard, from 4.8kHz to 11kHz, and sample rates as high as 17.8kHz available, as many as eight variable length messages may be stored. The messages are stored in battery backed-up RAM. The recorder from **GetTech** measures 2.6" × 2.6".

Circle (502) on Fast Fact Card

Two-way transceiver leaves caller ID code if user does not answer

The SmallTalker IV two-way transceiver allows the user to selectively signal another user. If the user being called does not answer, the caller can leave an ID code on the called unit's LCD, indicating that a call was received and from whom. The transceiver, from **Falcon Direct,** operates in the 146MHz–174MHz range for VHF and in the 450MHz–480MHz range for UHF.

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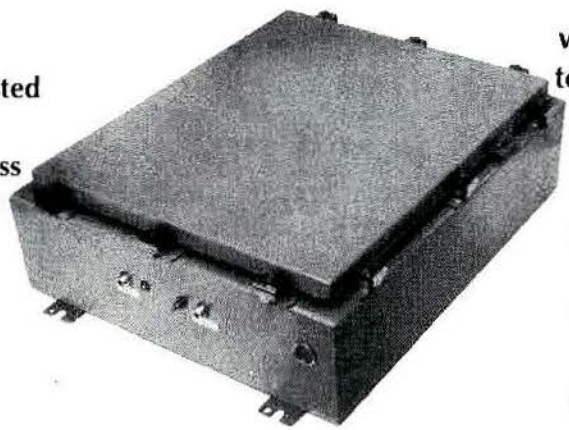

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SINCLAIR

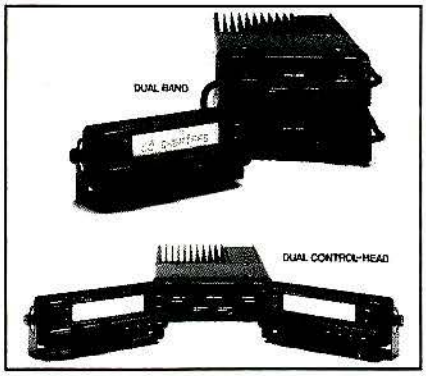
Circle (76) on Fast Fact Card

Logic-ready SMR core repeater has PC-programmable modules

The T-800 "Slimline" logic-ready SMR core repeater from **Tait Electronics** is an 800MHz–960MHz unit. The transmitter and receiver modules are mounted behind a rack-mountable front panel with a built-in speaker and a hand microphone. Transmitter output power is adjustable and rated for 1W–5W continuous duty to 50°C and 1W–2W to 60°C. Receiver characteristics include −117dBm sensitivity, −85dB selectivity, −100dB spurious rejection and −80dB intermodulation specifications. The transmitter and receiver modules are both PC-programmable for as many as 128 frequencies.

Circle (370) on Fast Fact Card

Mobile radio series allows optional dualband or dual head operations



The TK-630, TK-730 and TK-830 "30 series" mobile radios feature dualband, dual control head options. The radios, from **Kenwood Communications**, feature PC programmability, rotary controls, front-mounted speakers and backlit keys. The dualband option allows one control head to control two bands, thus allowing VHF and UHF transmissions from one radio. The dual control head option allows communication from two separate locations in a large vehicle. Full-featured control panels have a 12-digit alphanumeric LCD and 32 channels divided into two groups.

Circle (371) on Fast Fact Card

System monitor's detect and latch attack time is in microsecond range

ElectroCom Communications Systems' Fast-attack Transmit Alarm (FTA) P/N 505-10156 transmission system performance monitor detects a low-power or high-VSWR condition during short-duration packet data transmissions. With a detect and latch attack time in the microsecond range, the FDA is suitable for telemetry, point-to-point, SCADA and voice applications. The FTA is designed to work with an in-line RF power sensor. In the low-power alarm configuration, one FTA can monitor the performance of two transmitters. When configured as a low-power/high-VSWR alarm, one FTA is required for each transmitter. The FTA has been designed to work with any transmitter with an attack time of 500 microseconds to 500 milliseconds.

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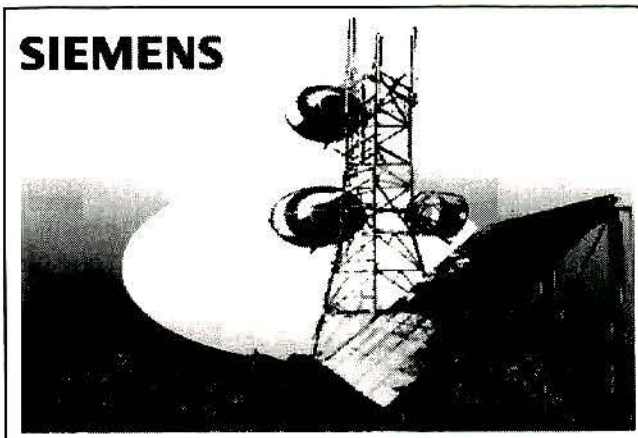

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Circle (80) on Fast Fact Card

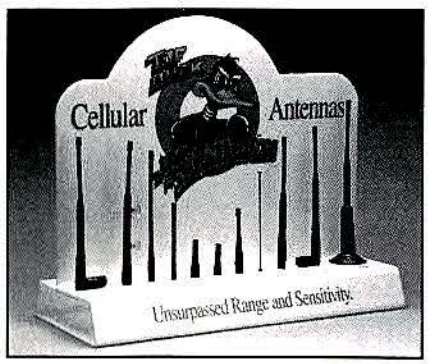
New products

Complete radio control system functions like a PBX environment

The Radio Access Control System (RACS) from **Zetron** is a wide-area communications system for utilities and other geographically extended organizations. The RACS provides a network for mobiles, portables, pagers, base stations, repeaters, telephones and other devices in a single PBX-like environment. The front end, the 7D+ Dispatch Control Station, is a desktop unit with function keys and on-demand monitoring. The two other main components of the RACS system are the 7032 Radio Dispatch Switch and the 47R Site Controller. The site controller, a full-featured repeater control panel, interfaces directly with a duplex station and provides all repeater control shelf functions, including audio processing and CTCSS and DCS encode and decode.

Circle (373) on Fast Fact Card

Display, guides promote antenna products availability, compatibility



Point of purchase cellular products displays with attached antenna samples are available from **Centurion International**. The displays are designed for manufacturer's representatives, dealers and distributors of Centurion products. Centurion also offers a pocket-size slide rule to allow cross-referencing of cellular phones with the appropriate replacement antenna style. The guide is available to all cellular phone dealers, distributors and carriers who handle Centurion products.

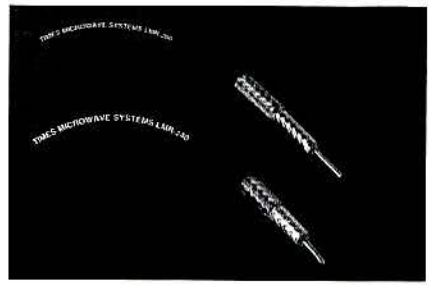
Circle (374) on Fast Fact Card

Tower monitor activates spare lamp or triggers remote alarm system

The SCR430T universal electronic lamp alarm relay from **SSAC** can monitor as many as four 620W flashing tower beacons or four 116W tower side lamps. The number of lamps, their wattage and voltages are selected via switches on the unit. The unit's toroidal transformer constantly monitors the current in the lamp wiring. Current drops will trigger an LED display and an output transfer, although a six-second trip delay prevents nuisance tripping. The solid-state line voltage output can operate a spare lamp or alarm, and isolated SPDT relay contacts rated at 10A resistive can be used for a remote alarm system. The SCR430T operates on 120Vac. The circuitry is fully encapsulated.

Circle (375) on Fast Fact Card

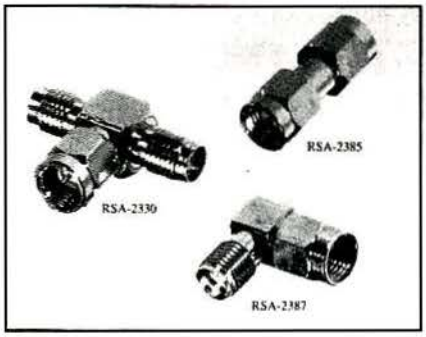
Low-loss cables provide options for two-way mobile, cellular, PCN uses



The LMR-200 and LMR-240 flexible communications cables from **Times Microwave** are low-loss cables designed for use in cellular, PCN and two-way radio mobile antenna feeder applications. The low-attenuation cables are constructed with a bonded aluminum tape and an overbraid outer conductor with a foam polyethylene dielectric to reduce loss and improve RF shielding.

Circle (376) on Fast Fact Card

Subminiature connectors handle dc to 18GHz at 50Ω impedance



Subminiature RF connectors are now available from **RF Industries.** The SMA connection series is designed to offer reliable broadband performance from dc to 18GHz at a consistent 50Ω impedance. The SMA series includes connectors for flexible cable and for semi-rigid cable. Both in-series adapters and between-series adapters are included. Most of the SMA adapters are manufactured to ISO 9002 standards.

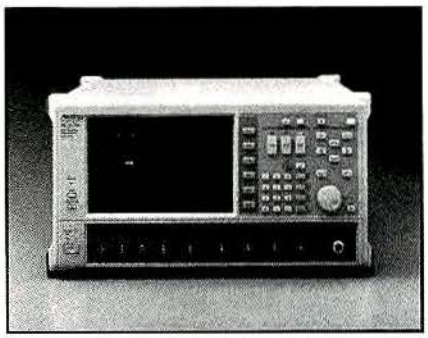
Circle (377) on Fast Fact Card

Software offers billing alternatives for smaller customer base systems

The SRS Billing Manager software from **Quantum Publishing** creates a computerized billing system for smaller cellular, paging, trunking and conventional radio operators. The DOS-based system offers a billing range from the 100s to 50,000 customers and the ability to stand alone or to be LAN-based. In its basic form the system will run on a 386 PC. For larger capacity a file server or multi-user access can be used. The system runs record processing and sorting overnight. Service personnel can directly access customer service modules and billing histories.

Circle (378) on Fast Fact Card

Digital modulation signal generator yields high-quality, low-noise signals



The MG3670A digital modulation signal generator from **Anritsu Wiltron** is equipped with a built-in, high-performance quadrature modulator for accurate evaluation of digital mobile communications equipment. Covering a frequency range of 300kHz to 2.1GHz, the signal generator has a variable output from −143dBm to +13dBm. Low adjacent channel leakage power ensures accurate measurements of third-order intermodulation distortion and adjacent channel selectivity. Specially designed AGC circuitry incorporated into the MG3670A produces precise output at levels as low as −143dBm with stable frequency characteristics. The signal generator has a wide IQ bandwidth specified to 1.2MHz (typ. 5MHz) to support future wideband formats.

Circle (379) on Fast Fact Card

Rapid charger protects batteries with an initial low voltage

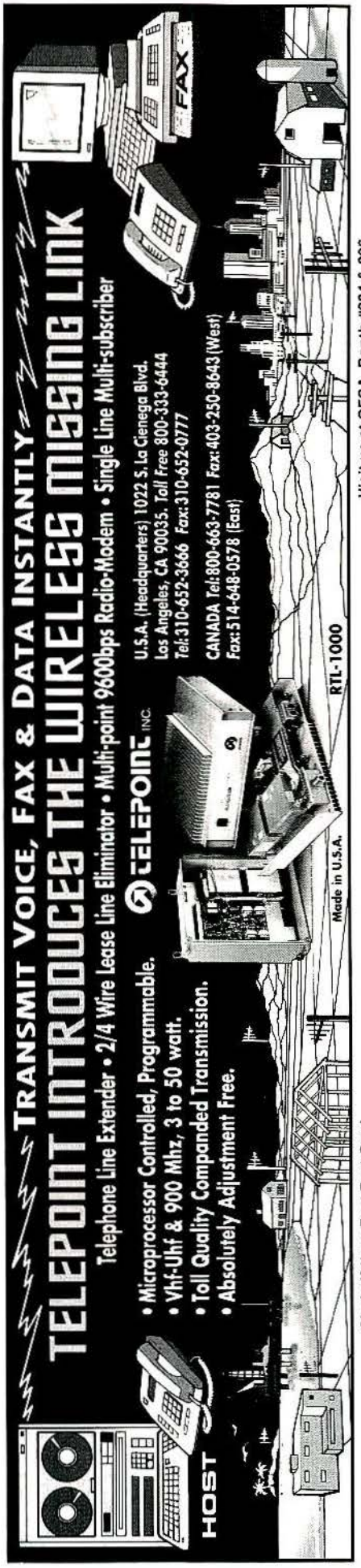
Designed for use with the T-20 hand-held radio, the DC-20 desktop battery charger from **Tekk** is a microprocessor-controlled, one-hour rapid charger employing negative delta V sensing for determining charge level. The charger includes a low-battery protection mode that trickle-charges until sufficient voltage is detected for rapid charge without damage. Charge rate and status are indicated by red and green front panel LEDs.

Circle (380) on Fast Fact Card

Pager fashion accessories impart color accent to personal paging

Hot Tops and Hip Clips from **Motorola** are pager accessories designed to snap onto the top and belt clips of FreeSpirit pagers. The accessories, designed as fashion accents for the consumer market, are available in three bright colors: "Rythm & Blue," "Techno Teal" and "Rockin' Red."

Circle (381) on Fast Fact Card



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Circle (82) on Fast Fact Card

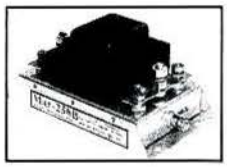
New products

Test set adapter measures quality of CDMA transmitter waveforms

The HP 83203A CDMA adapter from **Hewlett Packard** allows measurement of of transmitter waveform quality for CDMA mobile telephones and base stations. The adapter is used in conjunction with the HP 8920A RF mobile test set and the HP 8921A cell-site test set. The adapter measures waveform quality using a power-correlation coefficient methodology developed by Hewlett Packard. The HP 83203A also reports frequency accuracy and static-time reference accuracy. The adapter tests the root-mean-square, error-vector magnitude, amplitude error, phase error and carrier feedthrough present in the transmitted signal.

Circle (382) on Fast Fact Card

Noise filter accommodates increased amperage in PS vehicle alternators



The MAR-250A alternator noise filter addresses the increased interference problem presented by the use of newer, larger 200A alternators on public service vehicles. The filter is designed for all 6V–32Vdc negative-grounded systems and handles 250A continuously with 350A intermittent duty. Applications for the filter, available from **Marine Technology**, include AM/FM/SSB/VHF radiotelephones, public address systems, dc-to-ac inverters and Loran-C navigation equipment. Smaller 70A and 120A alternator filters are also available.

Circle (383) on Fast Fact Card

Compact hand-held VHF radio provides privacy option, 5W power

The T-50 hand-held is a compact VHF radio designed for most industrial communications requirements. The radio is FCC type accepted. The 5W hand-held, from **Tekk**, features four channels, a DIP-switch programmable privacy option, a speaker/microphone jack and an optional one-hour charger.

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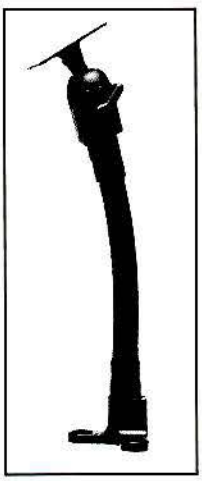
Circle (83) on Fast Fact Card

Portable, mobile units use services available on digital SMR system

The Lingo phone series from **Motorola** includes the L3000 multi-service portable phone with flip and the LM2000 multi-service mobile phone. The units connect users to voice dispatch, wireless phone, Message Mail and data services that are available on the Motorola Integrated Radio System (MIRS). The L3000's features include an alphabetical directory, quick scroll and user programmability, all from the keypad. The LM2000's features include hands-free operation, speed dialing and illumination of the keypad, LCD and handset cradle for nighttime use.

Circle (385) on Fast Fact Card

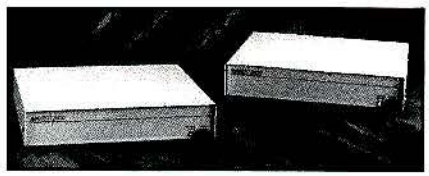
Rugged communications mount allows for liberal swivel and tilt



PanaVise Products' Uni-Flex mobile communications mount features a patented "pinch design" that prevents loosening at the foot. The double-wound flex shaft has a heavy-duty vinyl coating for increased protection, strength and durability. A universal joint under the mounting plate allows 210° of pivot and 360° of swivel. The mounting plate is NEC/AMPS-compatible with set-screw or knob adjustment. The mount is available in rises of 10", 12" and 14".

Circle (386) on Fast Fact Card

Wireless data system comprises four network station components



An out-of-the-box solution for building wide-area, multipoint, multi-access private wireless data networks is provided by the MAVRIC 2000 system. The wireless data system from **Metric Systems** consists of four network station components: host station, remote station, repeater and hub station. The system provides wireless data communications between remote terminal equipment, computers, LANs and public or private wireless data systems operating in the VHF/UHF or 800/900MHz bands.

Circle (387) on Fast Fact Card

High-power, remote cell extends coverage, capacity for cellular

Peninsula Engineering's MRC-800 high-power remote cell extends coverage and capacity for cellular networks. The remote cell provides 10W per channel, 100W–500W ERP and as many as 16 channels of cellular capacity. The MRC-800 has an integrated microwave link to the donor base station that allows the remote cell to maintain full cellular system transparency.

Circle (388) on Fast Fact Card

Pager protector prevents damage from impact, dust and moisture

The SCUBA (Sophisticated Colorful Underwater Beeper Accessory) from **Quality Products** protects pagers from the elements during athletic or outdoor activities. The impact-resistant, weather-proof case is designed with internal support posts to keep the pager suspended. The case comes in a variety of transparent colors, allowing the user to read the display through the case. It also has a clip back and a heavy-duty, adjustable nylon lanyard. The SCUBA will hold the Bravo, Bravo Plus, Express and other pagers.

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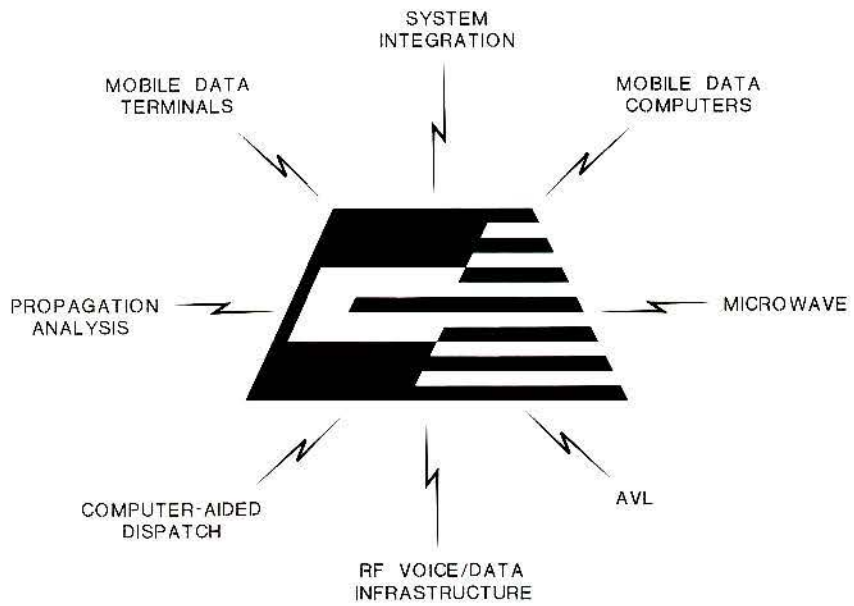

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New products

Service monitor combines multiple tests in one unit

The CMS 54 RF Communications monitor is being marketed and supported in the United States and Canada by **Tektronix** under a strategic alliance with the manufacturer, Rohde and Schwarz. The CMS 54 combines in a single unit: a spectrum monitor, an adjacent-channel power meter, a harmonics meter, and the ability to measure frequency and power transients. The monitor has a large, high-resolution, front-panel, backlit LCD with graphics capability. Application-specific test routines can be tailored by the user and are automatically included in the softkey menu.

Circle (390) on Fast Fact Card

Software allows scheduling of outgoing pager messages

Taplink is an alphanumeric software package from **PageTap** that allows the user to preprogram messages to be sent to an alphanumeric pager at any time, anywhere in the world. The feature doubles as a personal secretary, allowing users to send reminder messages to themselves. Taplink is compatible with any PC-DOS system and is secured with an included Dongel device to prevent unlicensed use.

Circle (391) on Fast Fact Card

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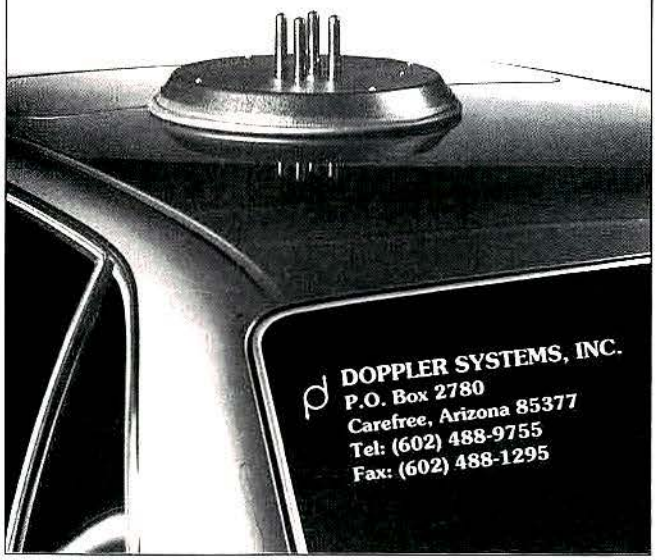

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Circle (87) on Fast Fact Card

Literature

Catalog features test equipment

A 244-page catalog features test instruments and tools for engineers, managers, technicians and hobbyists. Included are DMMs and accessories, soldering tools, custom tool kits, EPROM programmers, power supplies, ELF meters, reference books, breadboards, scope meters, datacom tools and testers, adhesives, measuring tools, precision hand tools, and portable and benchtop digital storage scopes. The catalog from **Contact East** lists communication test equipment, magnifiers, inspection equipment and workbenches.

Circle (450) on Fast Fact Card

Catalog describes coaxial connectors

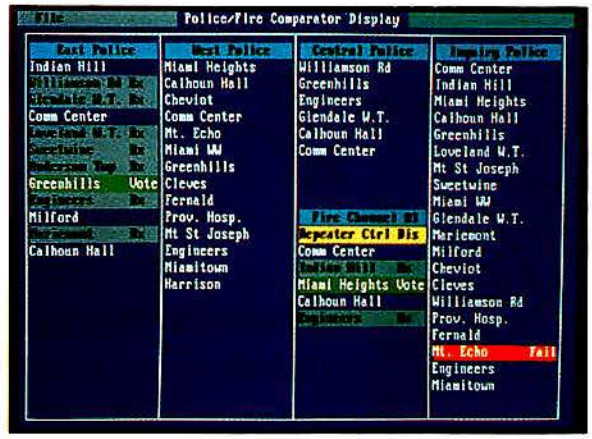
A 36-page catalog focuses on type N coaxial connectors from **Delta Electronics Manufacturing.** The connectors are presented in a logical format, offering the user a wide variety of choices in plating; cable clamping types; receptacle configurations and MIL specifications, including MIL-C-39012 and MIL-A-55339 QPL connectors and adapters. The high-resolution drawings are proportionally accurate and can be easily scaled and reproduced for use on internal specification drawings. Included in the catalog are the "Tee" plugs and jacks, which add flexibility and versatility to many system designs.

Circle (451) on Fast Fact Card

Catalog features 200 new products

A catalog from **Maxrad** lists more than 200 new models of land mobile, cellular and base station antennas and related accessories.

Circle (452) on Fast Fact Card



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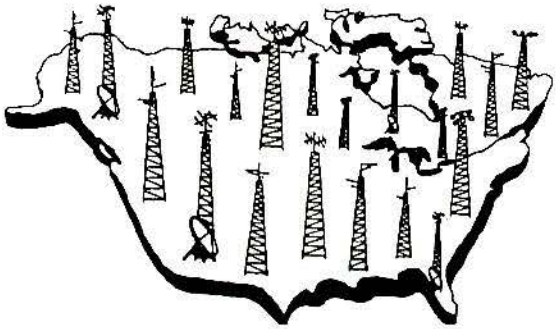

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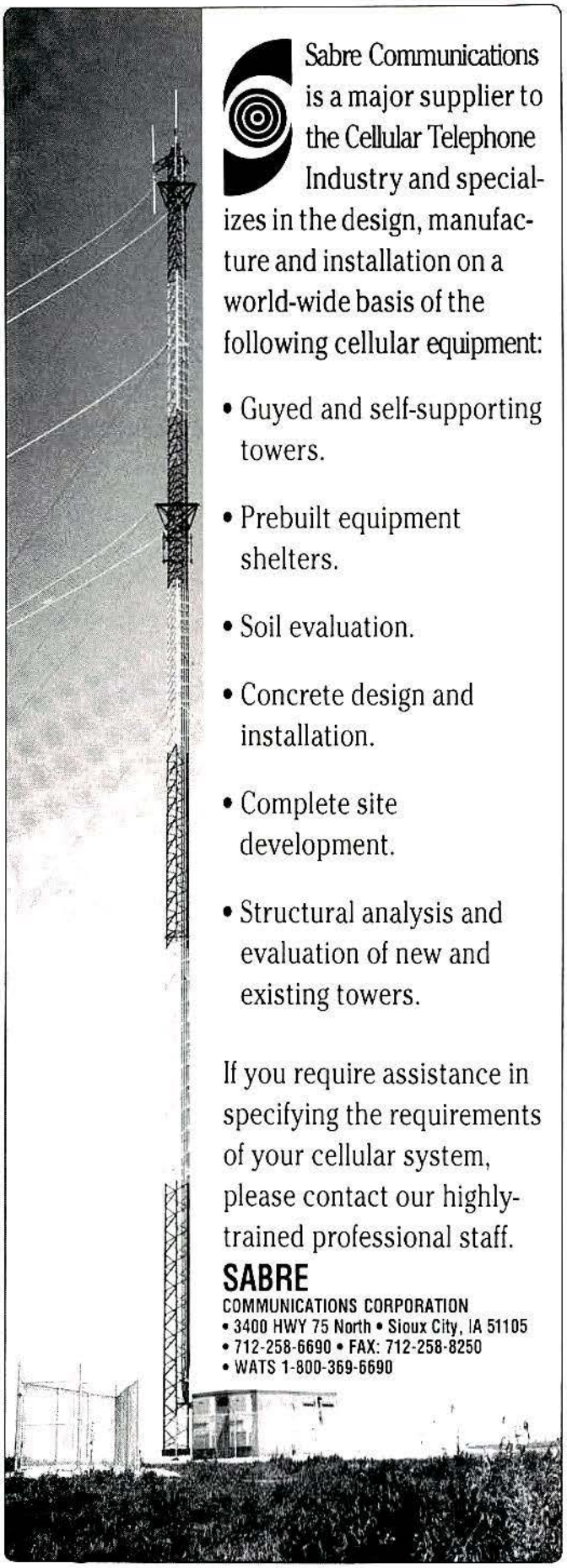


Visit us at UTC, Booth #548 Circle (91) on Fast Fact Card

People

Changes at Allen Telecom Group (ATG), Cleveland:

Jack Krisel departs Tandy as communications products and accessories manager to become mobile antenna product manager for Allen Telecom Group's A/S Mobile Division in Cleveland.

Ray Montalvo, international systems engineer for Latin America, moves up to sales manager for Mexico.

Fraser Clayton leaves Philips Mobile Communication Systems, Melbourne, Australia, as senior quality manager to join ATG as technical manager, Australasia Division.

Frank Meng exits Peninsula Engineering Group, Sunnyvale, CA, as vice president of international sales and marketing to become managing director, Asia/Pacific for ATG.

Ken Czosnowski leaves TDK Corporation of America, Mt. Prospect, IL, as account executive to join ATG as major account manager for the Midwest. He will work out of ATG's Chicago office.

Mike Halliday leaves Motorola Communications & Electronics Northwest Trading Area, Bellevue, WA, to become Northwest major account manager for ATG in the company's Seattle office.

Mark Gross departs TDK, Mt. Prospect, IL, as account manager to join ATG as Midwest regional sales manager in the Chicago office.

Mark Smith exits Valor Enterprises, West Milton, OH, as cellular division sales manager to become cellular sales specialist with ATG in its Cleveland office.

Mike Barker, senior vice president of sales and marketing for Intervoice, Dallas, advances to executive vice president.

Changes at the Personal Communications Industry Association (PCIA), Washington, DC:

Thomas A. Stroup resigns as president of PCIA to become president of Columbia Spectrum Management, Alexandria, VA.

Lois M. Irwin departs Phillips Publishing, Potomac, MD, as editor of *PCS News* to become news and information manager for PCIA.

Oggie Reyna, customer service representative for Advance Label and Tag, McKinney, TX, advances to international marketing and sales coordinator.

R.A. Kleine retires as vice president of marketing and sales with UNR-Rohn, Peoria, IL. He will continue to serve as a consultant.

Changes at Hatfield Associates, Boulder, CO:

Dale N. Hatfield, founder and president of the company, is appointed chief executive officer and senior consultant.

Dr. Robert A. Mercer, senior vice president, advances to president.

Harold C. (Hal) Davis exits Advanced MobileComm, Boston, as chief technical officer to become executive vice president for business development at SmartLink, Wallingford, CT.

Changes at Pinpoint Communications, Dallas:

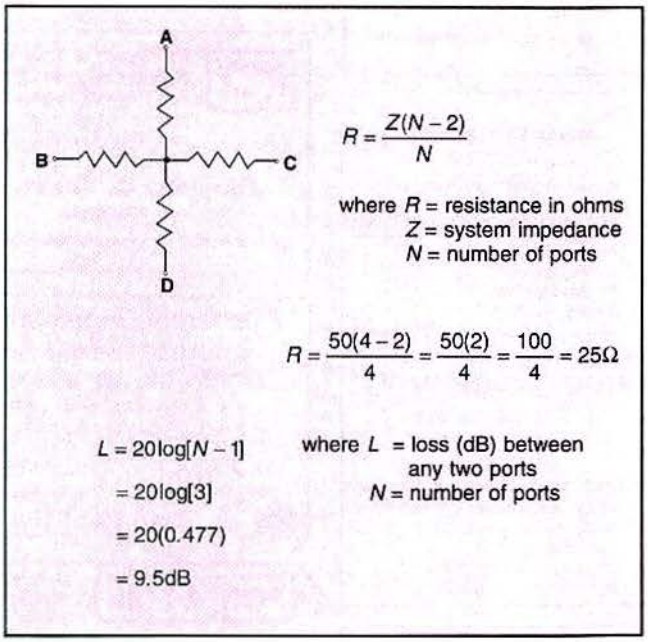
Joseph E. Andrulis leaves McKinsey & Co., Dallas, as an associate specializing in organizational performance and marketing strategy to join Pinpoint as a marketing manager.

Patrick G. Bromley, company director, moves up to chairman of the board.

Letters from readers

Corrections:

Figure 3 on page 8 in the February 1994 "Technically Speaking" column contained errors in the logarithmic calculation. A correct version, formatted so you can remove it and place it over the original Figure 3, appears below:



When printed in the February 1994 issue, the following news item contained an incorrect part number. The correct part number appears in this reprinted version:

Stabilant wins listing in Motorola book, catalog

Stabilant 22A, a contact enhancer made by D.W. Electrochemicals, Richmond Hill, Ontario, is available from Motorola's Worldwide Systems & After market Products Division, telephone 800-422-4210. The 15ml service kit is Motorola Part No. 11-80639E78 and is listed in the "Buyers Source Book" and the "Tools & Shop Supplies Catalog." A small amount of the contact enhancer applied to an electromechanical contact substantially improves the contact's reliability.

Fast Fact Card comments:

The toughest problems facing me on the job are obtaining replacement parts and literature.

Robert Ravenscroft
Columbia Gas Transp.
Cumberland, MD

The toughest problem facing me on the job is having technicians understand the trunking format.

Eddy Yee
Kensington, PA

The toughest problem facing me on the job is getting an RCC frequency.

Tomas Ayala Torres
Rapid Page
Ponce, Puerto Rico

The toughest problems facing me on the job are:

- Lack of information.
- Suppliers that cannot meet orders.

T. Mochoruk
B C Hydro
Hudson Hope, British Columbia

The two toughest problems facing me on the job are:

- Test equipment cost.
- Site congestion.

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Help wanted

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Joyce Bollegar
Classified Sales

Advertising rates in **Mobile Radio Technology's** Classified section are $72.00 per column inch, per insertion, with frequency dis-counts available. There is a one inch minimum.

Ads larger than one inch are sized in 1/4-inch increments and billed accordingly, as determined by total size of the ad, including ruled borders and rounded up to the nearest 1/4 inch.

Blind box ads (replies sent to **MRT** for forwarding) are $30.00 and Fast Fact reader service numbers are available for 25.00 per service, per insertion, to cover process and handling costs.

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Must have 3-5 years' troubleshooting cellular equipment to debug RF and T-1 line problems. Some positions require extensive domestic/international travel.

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Must have an administrative background plus 1-3 years' network planning experience (DC power systems, antennas, patch bays, transmission equipment) or 3-5 years of experience troubleshooting cellular/telco systems.

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Will handle scheduling and change orders, and coordinate installation. This includes responsibility for local contracts with subcontractors, program reviews, weekly reporting, inventory management, customer interface for status reviews, lease asset management, and order input and tracking.

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MASTR II 450-470 40W w/preamp	125
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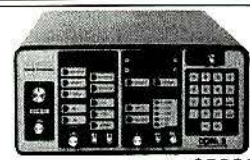

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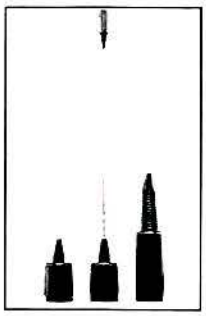

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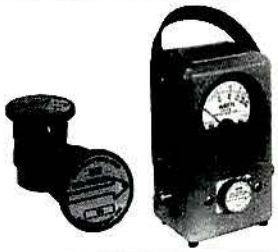

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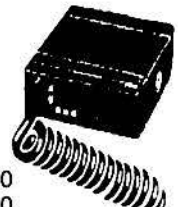

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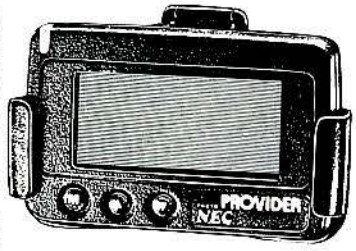

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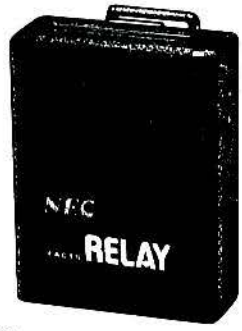

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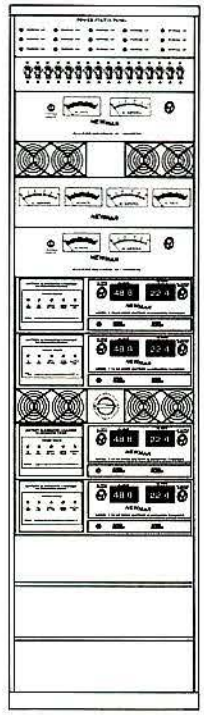

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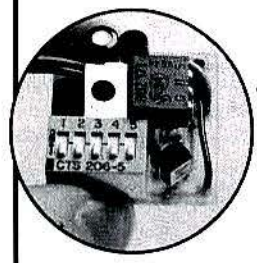

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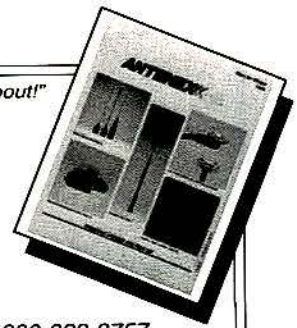

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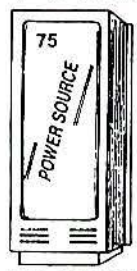

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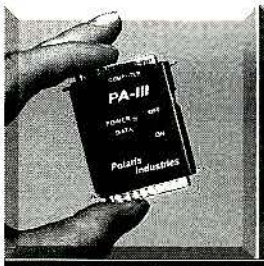

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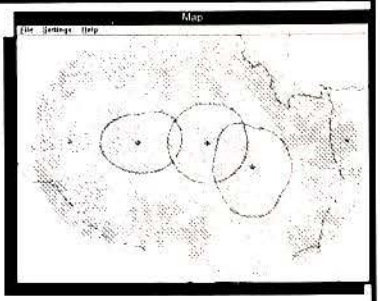

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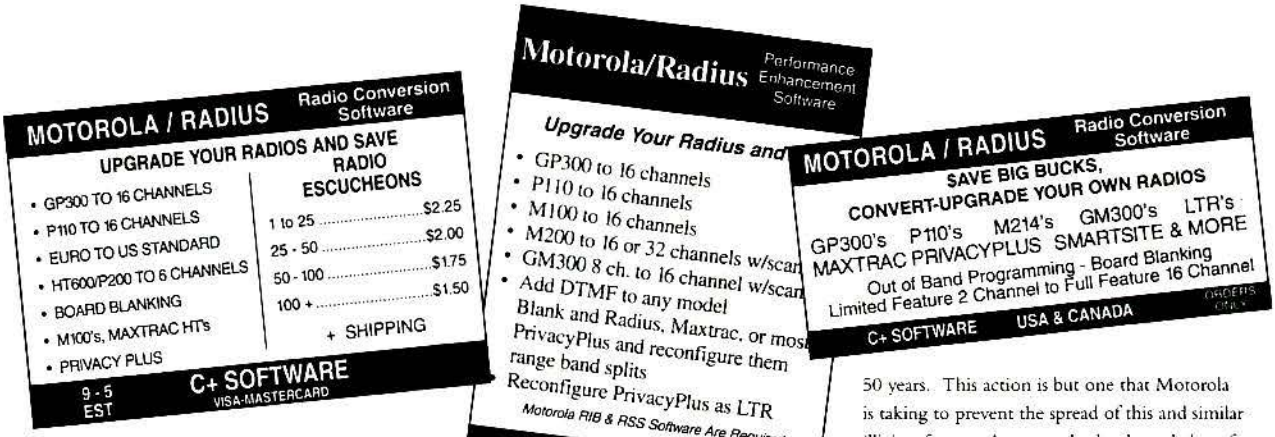

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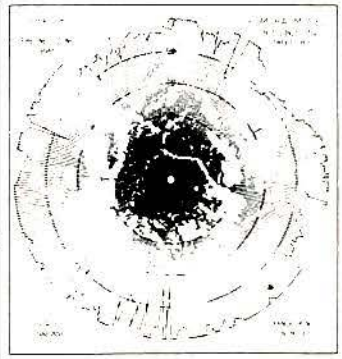

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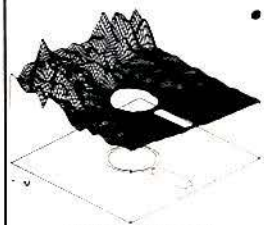

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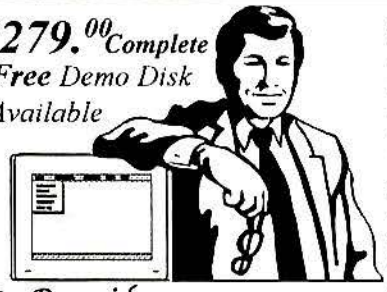

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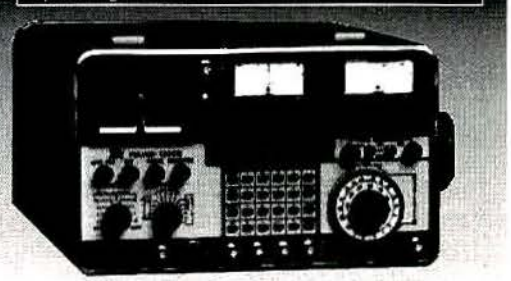

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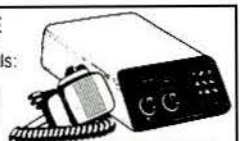

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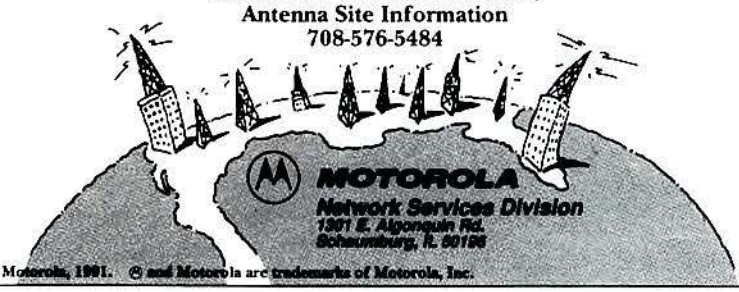

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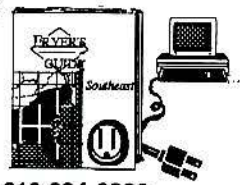

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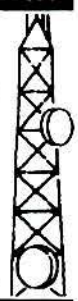

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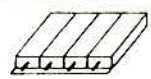

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Automation & Electronics Engr.	100	121	800-527-4596
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Schurman Electronics	103	131	603-447-3925
Sentry USA	104	134	407-773-6090
Sharp Communication	103	132	800-548-2484
Sinclair Radio Laboratories	36,80	33,76	800-288-2763
SMC Electro-Mount	26	23	800-527-1079
Softwright	106	138	303-344-5486
Solar Electric Specialties	81	78	800-344-2003
Sonic Communications Inc.	34	31	800-688-1944
Stancil Corporation	69	65	714-546-2002
Standard Communications	53	49	800-767-6695
Sti-Co Industries, Inc.	44	42	716-662-2680
Survey Technology	66	62	503-591-5986
Tait Electronics USA, Inc.	50	46	713-984-8684
Telemessaging Devices Inc.	74	70	800-645-4595
Telepoint, Inc.	83	81	310-652-3666
Telewave, Inc.	56	52	415-968-4400
TGA Systems Inc.	16	14	404-441-2100
Times Microwave Systems	64	60	203-949-8400
Tower Watch	109	150	913-233-2343
Transcrypt International Ltd	3		800-228-0226
Transtronics Inc.	86	87	913-841-3089
Trilogy Communications Inc.	11	9	601-932-4461
Trylon Manufacturing Co. Ltd.	87	89	519-669-5421
Vega, A Mark IV Company	1	4	818-442-0782
Versatel Communications	96	111	800-456-5548
Vocom/RF Corporation	30	27	800-USA-MADE
Wacom Products Inc.	84	83	817-848-4435
WAVETEK	52	48	800-245-6356
Wetec Electronics	100	123	901-286-6275
Wilmore Electronics Company	37	34	919-732-9351
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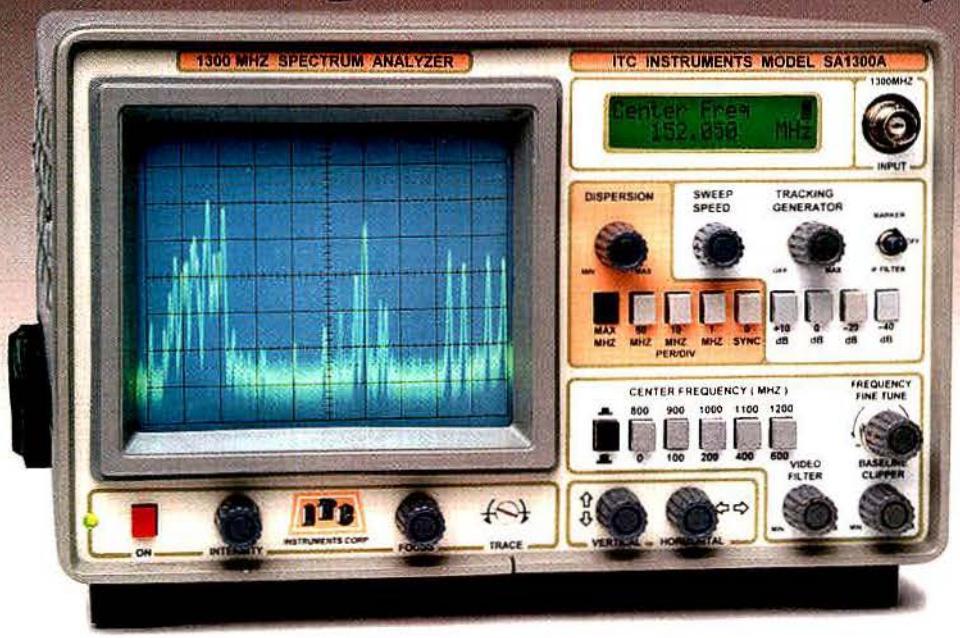

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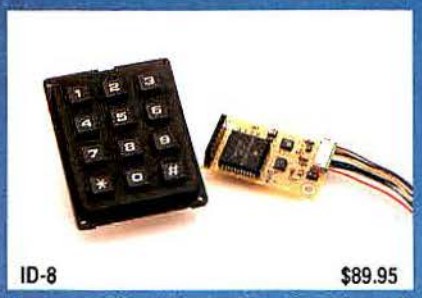

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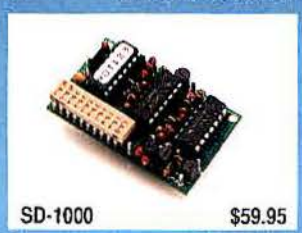

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